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April 20, 2017

Robert Kaplan
Acting Regional Administrator
U.S. Environmental Protection Agency - Region 5
77 West Jackson Blvd.
Chicago, IL 60604-3507

Subject: Supplemental Information for 2015 Ozone National Ambient Air Quality Standard (NAAQS) Area Designations

Dear Mr. Kaplan:

On October 1, 2015, the U.S. Environmental Protection Agency (EPA) revised both the primary and secondary ozone NAAQS. On September 21, 2016, in accordance with section 107(d)(1)(A) of the Clean Air Act (CAA), Governor Walker recommended that all counties in Wisconsin be designated as attainment for this standard. In support of the governor's recommendation, the Wisconsin Department of Natural Resources (WDNR) is submitting the enclosed technical support document (TSD). EPA should consider this supporting information and ensure it is reflected in any modifications to the governor's recommendation EPA elects to make in the "120 day" notifications that would occur prior to final designations.

While the general concept of ozone formation and transport in the Lake Michigan basin has long been recognized, this TSD incorporates data from a variety of sources, some of which were unavailable until recently. This includes:

- Analysis of ozone data from the lakeshore and inland monitors operated by WDNR in both Sheboygan and Kenosha counties to help understand the lakeshore ozone gradient;
- Analysis of wind data when values above the 2015 ozone standard have been measured at shoreline monitors;
- Recent HYSPLIT and source apportionment modeling results;
- Photochemical modeling conducted by the Lake Michigan Air Directors Consortium (LADCO).

The result is a comprehensive, multifaceted analysis of the origins, transport, and impacts of ozone along Wisconsin's Lake Michigan shoreline. This technical document supports several important conclusions:

- Elevated ozone levels are confined to an extremely narrow band that follows Wisconsin's shoreline, with air quality improving dramatically just a few miles inland;
- Ozone concentrations measuring above the level of the 2015 ozone NAAQS at the state's lakeshore monitors occur almost exclusively when the wind is coming from over the lake, not from over Wisconsin;
- Ozone concentrations at Wisconsin's lakeshore monitors are primarily due to emissions originating from outside the state;

- Additional emissions reductions from the areas around Wisconsin's shoreline monitors, including the state's most populous areas, would not meaningfully change the design values at those monitors. In fact, in some cases such reductions would actually increase ozone concentrations.

This last point is of particular significance to the designation process. Historically, EPA has designated areas around violating monitors (typically, entire counties or metropolitan areas) based on the premise that nearby sources of VOC and NOx emissions contribute to locally monitored ozone concentrations. The TSD, however, provides incontrovertible evidence to the contrary. Specifically, photochemical modeling shows that hypothetical (and unrealistically large) additional cuts in VOC and NOx emissions in ten eastern counties – including the entire Milwaukee metro area – would only reduce ozone design values by an average of 0.1 ppb. This impact is insignificant, equating to about one tenth of one percent of the 2015 ozone NAAQS of 70 ppb.

This effect is even more pronounced in Sheboygan County. It is widely recognized that Sheboygan County's Kohler Andrae monitor, which regularly registers the highest ozone concentrations in the state, is greatly affected by ozone transport due to its location.[1] This TSD quantifies, for the first time, the county's own contributions to ozone levels at that monitor. New modeling shows that, even if it were possible to eliminate *all* manmade sources of VOC and NOx emissions in Sheboygan County – a clearly impossible scenario – ozone design values at the Kohler Andrae monitor *would not decrease at all*. In fact, the data indicates that ozone values might actually *increase*. The irrefutable conclusion – that Sheboygan County has no ability to reduce ozone values at the Kohler Andrae monitor – has obvious and significant implications on the designations process.

The governor noted in his September 21, 2016 letter that, if EPA elects to designate areas of the state as nonattainment, EPA should ensure that the geographic scope of these areas is minimized. Chapter 6 of the TSD describes the maximum geographic extent that could be considered by EPA, based on the latest available monitoring data and extensive analysis of the "lake breeze" effect that transports high ozone air to the Wisconsin lakeshore. Any nonattainment areas EPA elects to impose must adhere to this science-based, "distance from the shoreline" approach, rather than on arbitrary boundaries based on historical practice or outdated theories of how local emissions impact ozone levels in the state.

This submittal provides compelling, data-driven evidence for what has long been understood: Wisconsin's ozone problems are due to transported pollutants, exacerbated by the unique effects of Lake Michigan, and are not meaningfully affected by in-state emissions. EPA's repeated unwillingness to fully address the impacts of ozone transport on Wisconsin has left the state to address its nonattainment issues on its own. Wisconsin has met this challenge by implementing many measures to reduce pollutants and operating one of the best-controlled utility fleets in the nation. However, the science is clear: there are no demonstrable benefits to be gained by further controlling emissions in the state for the purpose of this standard. EPA must acknowledge this information, and use the discretion it has under the CAA to avoid imposing nonattainment areas on the state that would not improve air quality.

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[1] EPA acknowledged this as recently as its January 2017 preliminary transport modeling for the 2015 ozone standard, in which ten upwind states were shown to contribute significantly to this monitor (this modeling also predicted a 2023 design value at this monitor of 71 ppb, which would exceed the standard).

I am available to discuss the information contained in this letter and TSD further if needed. Please contact me at Gail.Good@wisconsin.gov or 608-264-8537 if there are any questions regarding this submittal.

Sincerely,

Gail E. Good

Gail Good
Director
Air Management Program

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Enclosure

2015 Ozone National Ambient Air Quality Standards Area Designations

Technical Support Document

Wisconsin Department of Natural Resources

April 2017

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List of Acronyms

CAA	Clean Air Act
CFR	Code of Federal Regulations
CBL	Convective boundary layer
CSAPR	Cross-State Air Pollution Rule
DV	Design value
EPA	U.S. Environmental Protection Agency
HYSPLIT	Hybrid Single-Particle Lagrangian Integrated Trajectory
LADCO	Lake Michigan Air Directors Consortium
LMOS 2017	Lake Michigan Ozone Study 2017
MDA8	Maximum daily 8-hour average ozone concentration
MSA	Metropolitan Statistical Area
NAAQS	National Ambient Air Quality Standards
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NOx	Nitrogen oxides (NO and NO_2)
ppb	Parts per billion
ppm	Parts per million
RTA	Rural Transport Area
SIP	State Implementation Plan
TSD	Technical support document
VOC	Volatile organic compound
WDNR	Wisconsin Department of Natural Resources

1. Introduction and Background

On October 1, 2015, the U.S. Environmental Protection Agency (EPA) promulgated revisions to the primary and secondary National Ambient Air Quality Standards (NAAQS) for ozone. The revisions became effective on December 28, 2015. The revised NAAQS increased the stringency of both the primary and secondary 8-hour ozone standards from 0.075 parts per million (ppm) to 0.070 ppm (70 parts per billion (ppb)). The standards are based on the annual 4th highest daily maximum 8-hour average (MDA8) ozone concentration, averaged over three consecutive years. This average is referred to as the "design value" for each 3-year period.

On September 21, 2016, in accordance with section 107(d)(1)(A) of the Clean Air Act (CAA), Governor Walker recommended that all counties in Wisconsin be designated as attainment for this standard. This recommendation was based on: (1) ozone levels in the state have improved, (2) the state has already significantly decreased emissions, and (3) elevated ozone measurements in Wisconsin are primarily due to emissions originating from outside the state. This technical support document (TSD) has been developed by the Wisconsin Department of Natural Resources (WDNR) to support this recommendation. The analyses contained within also define the maximum extent of potential 70 ppb ozone design values in the state.

This submittal provides compelling, data-driven evidence for what has long been understood: Wisconsin's ozone problems are due to transported pollutants, exacerbated by the unique effects of Lake Michigan, and are not meaningfully affected by in-state emissions. EPA should consider this supporting information and ensure it is reflected in any modifications to the governor's recommendation EPA elects to make in the "120 day" notifications that would occur prior to final designations.

1.1. Document Overview

This TSD presents a comprehensive analysis of the origins, transport and distribution of ozone impacting Wisconsin's Lake Michigan shoreline.

Following this introduction, Chapter 2 contains ozone monitoring data for the years 2014 to 2016. Chapter 3 presents a conceptual model for ozone formation in the Lake Michigan region, highlighting the significant role that meteorology plays in this region. Chapter 4 examines a number of analyses that demonstrate that ozone-rich air is confined to a narrow strip of land following the lakeshore, with ozone concentrations dropping dramatically just a few miles from the lake. Chapter 5 shows that ozone along the lakeshore is due to transport from other states located to the south. This conclusion is based on a number of analyses, including back-trajectory (HYSPLIT) and source apportionment modeling, as well as modeling of different emission reduction strategies. These conclusions are based on the findings that ozone-rich air rarely penetrates inland and is almost exclusively the result of out-of-state source emissions.

Finally, should EPA elect to impose nonattainment areas in Wisconsin, Chapter 6 describes the maximum geographic extent that could be considered by EPA based on the evidence contained in this TSD.

1.2. Consideration of EPA's Designations Guidance

Information on the schedule and process for initially designating areas for the purposes of implementing the 2015 ozone NAAQS was provided by EPA in a February 25, 2016 memorandum, "Area Designations for the 2015 Ozone National Ambient Air Quality Standards." In this guidance, EPA states that "the boundaries for each nonattainment area should be evaluated and determined on a case-by-case basis considering the specific facts and circumstances unique to the area." The memorandum identified several factors that EPA intends to evaluate when making final nonattainment boundary decisions for this standard. These factors include:

- Air quality data,
- Emissions and emissions-related data,
- Meteorological data,
- Geography/topography, and
- Jurisdictional boundaries.

EPA's memorandum states that the agency will evaluate this and other information provided by a state when determining the appropriate nonattainment area designation. Wisconsin considered the above five factors in this TSD, as discussed below.

1.2.1. Air Quality Data

Ozone data from Wisconsin's air quality monitoring network is presented in Chapters 2, 4 and 5. In its guidance, EPA states that it intends to make final designation decisions for the 2015 ozone NAAQS using design values based on the 2014 to 2016 certified air quality data. The data presented in the TSD show that the only 2014 to 2016 ozone design values that exceed the 2015 ozone NAAQS in Wisconsin are located along the Lake Michigan shoreline. Chapter 4 demonstrates that ozone concentrations are highest along the lakeshore and decrease away from the shoreline along a sharply-defined gradient. The implications of this observed gradient for area designations are discussed in Chapter 6.

1.2.2. Emissions Data

EPA's guidance states that emissions of ozone precursor pollutants are important factors in the initial area designations process and that ambient ozone typically results due to a combination of regional and local emissions. A complete inventory of regional VOC and NOx emissions data for 2014, utilizing 2014 National Emissions Inventory and Clean Air Markets Division data, is included in Appendix A. A comprehensive list of permanent and enforceable control measures Wisconsin has implemented to reduce these precursor emissions can be found in Appendix B.

This TSD considers local and regional emissions data throughout the document to assess the impacts of these emissions on monitored ozone concentrations in Wisconsin. Specifically, these emissions are considered throughout Chapters 4, 5 and 6, including through source apportionment modeling, in the photochemical modeling results, and the multiple analyses characterizing the lakeshore ozone effect and gradient. These analyses conclusively show that emissions originating from outside the state of Wisconsin are the predominant contributors to the elevated ozone concentrations measured at the state's lakeshore monitors. These analyses also demonstrate that local emissions within these counties do not significantly affect ozone concentrations along the lakeshore and therefore are irrelevant for the purposes of considering nonattainment area boundaries.

1.2.3. Meteorological Data

EPA states that evaluation of meteorological data helps to assess the fate and transport of emissions contributing to ozone concentrations and to identify areas potentially contributing to monitored violations. This data may also support determination of nonattainment area boundaries. The unique meteorology of the Lake Michigan region is an extraordinarily important factor contributing to the elevated ozone levels measured along Wisconsin's lakeshore. Chapter 3 provides an overview of how this meteorology affects ozone formation and transport in the region. Chapters 4 and 5 examine in more detail the roles of lake breeze events and meteorologically-driven transport on ozone distributions in Wisconsin's lakeshore counties. This work includes, among many other elements, HYSPLIT (Hybrid Single-Particle Lagrangian Integrated Trajectory) back trajectory analyses.

1.2.4. Geography and Topography

EPA notes that physical features may influence the fate and transport of emissions, as well as the formation and distribution of ozone concentrations, and therefore may be relevant to defining nonattainment area boundaries. The geography of the Lake Michigan region has an important impact on ozone distributions in Wisconsin, particularly when combined with local and regional meteorological patterns. Chapter 3 discusses how the geography of the Lake Michigan region combines with meteorological patterns to create localized high ozone concentrations along Wisconsin's lakeshore. Chapters 4 and 5 further discuss how ozone patterns are influenced by geographical features, such as the angle of the shoreline, and how this geography impacts monitored ozone concentrations.

The topography of the entire Lake Michigan lakeshore basin is relatively flat and is not believed to significantly impact regional ozone concentrations or distribution.

1.2.5. Jurisdictional Boundaries

EPA's guidance says that existing jurisdictional boundaries may be considered for the purposes of providing a clearly defined legal boundary for potential nonattainment areas. However, where existing jurisdictional boundaries are not adequate to describe the area, EPA states "other clearly defined and permanent landmarks or geographic coordinates should be used."

The information contained in this TSD fully supports the governor's recommendation of September 21, 2016, which is that EPA should designate the entire state as attainment of the 2015 ozone standard. Should EPA elect to impose nonattainment areas on the state contrary to this recommendation, this analysis shows conclusively that using existing jurisdictional boundaries would not be appropriate for this purpose. Chapter 6 describes the maximum geographic extent that could be considered by EPA, based on the latest available monitoring data and extensive analysis of the meteorological patterns that transport high ozone air to the Wisconsin lakeshore.

This TSD also considers a number of tools and approaches that combine multiple factors into a comprehensive data analysis, presented in Chapters 4 and 5. Such approaches allow for a more complete understanding of how different factors work together to create the unique distribution of ozone observed in Wisconsin. This document presents ozone source apportionment modeling, as well as several other types of photochemical modeling, which combines the first four factors listed above to arrive at important conclusions relevant to the designations process.

A number of other types of analyses combine air quality data, meteorological data (in particular, wind direction analysis), and geography. Taken together, these analyses clearly describe how Wisconsin's Lake Michigan shoreline region is heavily impacted by transport of emissions from out-of-state sources to the south. In this environment, concentrated ozone formed over the lake is carried ashore by lake breezes, with ozone design values above 70 ppb being confined to a very narrow band along the shoreline.

1.3. Implications for EPA's Designations Process

The information contained in this TSD fully supports the governor's recommendation of September 21, 2016. Specifically, it is consistent with EPA's guidance, which notes that "for those portions of the area where an evaluation of the available information clearly establishes that emissions sources do not contribute to exceedances at the violating monitor(s), the EPA believes it would be appropriate to exclude that portion of the area from the nonattainment area." If EPA elects to act contrary to their own guidance and designate areas of the state as nonattainment, EPA should ensure that the geographic scope of these areas is minimized. Chapter 6 describes the maximum geographic extent that could be considered by EPA, based on conservative estimates of the extent of area with design values above 70 ppb. Any nonattainment areas EPA elects to impose must adhere to this science-based, "distance from the shoreline" approach, rather than on arbitrary boundaries based on historical practice or outdated theories of how local emissions impact ozone levels in the state.

2. Wisconsin Ozone Monitoring Data

Ozone levels in Wisconsin were monitored at 30 locations across the state from 2014 through 2016. The data was collected and fully quality-assured in accordance with the requirements of 40 CFR Part 50 and 40 CFR Part 58, Appendix A. Wisconsin's 2016 ozone data was certified by the state on February 9, 2017, and EPA concurred with the state's certification. EPA's guidance states that states and tribes can rely upon monitoring data for the purposes of area designations once it is certified in accordance with 40 CFR 58.15. Wisconsin's certified 2016 ozone data and the resulting design values are presented in this section and used throughout this document.

Table 2.1 lists the annual fourth-highest maximum daily 8-hour average (MDA8) ozone concentrations for the 30 monitoring locations and resulting design values. Design values are determined by averaging the annual fourth-highest MDA8 ozone concentrations for three consecutive years. A monitoring site meets the 2015 ozone NAAQS if the design value is less than or equal to 0.070 ppm (70 ppb). The only monitors with 2014-2016 design values measuring above the 2015 ozone standard are located along the Lake Michigan shoreline (see Table 2.1 and Figure 2.1). The Racine Payne and Dolan monitor in Racine County has only been operational for two years (2015 and 2016), so it does not have a 2014-2016 design value.

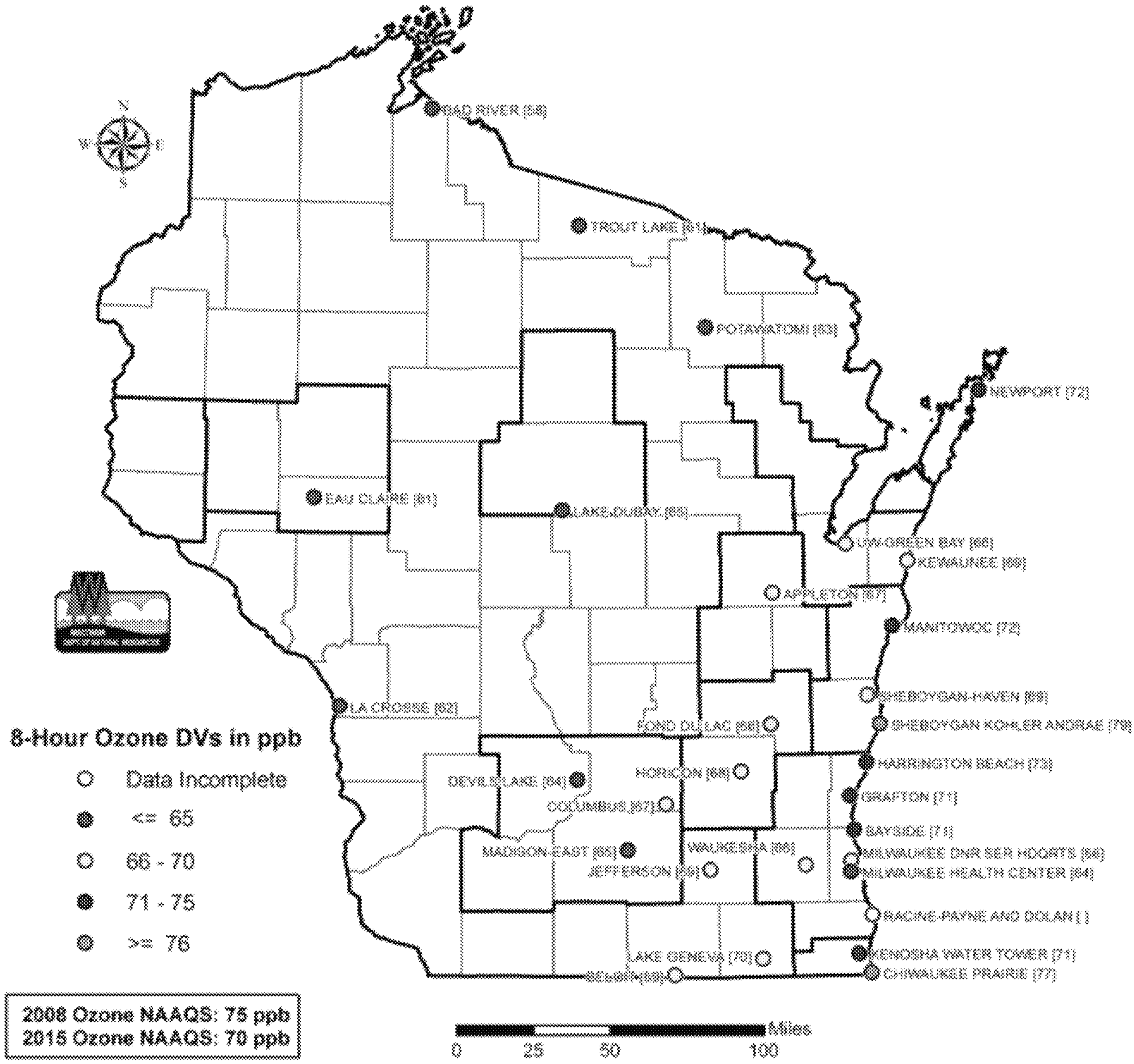
Ozone air quality data from Wisconsin's lakeshore monitors are analyzed in greater detail in Chapters 4 and 5.

Table 2.1. Annual fourth-highest daily maximum 8-hour average (MDA8) ozone concentrations and certified 2014-2016 design values (ppb). Locations with design values exceeding the 2015 ozone standard are highlighted. Annual fourth-highest MDA8 values exceeding 70 ppb are listed in bold.

Monitor ID	Site Name	County	2014	2015	2016	Design Value
550030010	Bad River Tribal School	Ashland	56	57	62	58
550090026	UW - Green Bay	Brown	66	65	68	66
550210015	Columbus	Columbia	69	64	70	67
550250041	Madison East High School	Dane	66	64	66	65
550270001	Horicon Wildlife Area	Dodge	**71**	66	68	68
550290004	Newport State Park	Door	65	**74**	**77**	**72**
550350014	Eau Claire	Eau Claire	61	59	64	61
550390006	Fond du Lac	Fond du Lac	67	65	66	66
550410007	Potawatomi	Forest	61	63	65	63
550550009	Jefferson – Laatsch	Jefferson	**71**	65	**71**	69
550590019	Chiwaukee Prairie	Kenosha	**76**	**75**	**80**	**77**
550590025	Kenosha Water Tower	Kenosha	70	68	**76**	**71**
550610002	Kewaunee	Kewaunee	65	70	**72**	69
550630012	La Crosse	La Crosse	63	61	63	62
550710007	Manitowoc / Woodland Dunes	Manitowoc	66	**77**	**74**	**72**
550730012	Lake DuBay	Marathon	64	63	68	65
550790085	Bayside	Milwaukee	69	68	**77**	**71**
550790026	Milwaukee DNR SER Headquarters	Milwaukee	68	66	70	68
550790010	Milwaukee 16th St. Health Center	Milwaukee	62	63	68	64
550870009	Appleton	Outagamie	70	66	66	67
550890008	Grafton	Ozaukee	**74**	70	**71**	**71**
550890009	Harrington Beach State Park	Ozaukee	70	**71**	**79**	**73**
551010020	Racine – Payne & Dolan	Racine	NA	68	**76**	NA
551050030	Beloit - Converse	Rock	**72**	64	**72**	69
551110007	Devils Lake State Park	Sauk	64	63	66	64
551170006	Kohler-Andre State Park	Sheboygan	**72**	**81**	**85**	**79**
551170009	Sheboygan - Haven	Sheboygan	68	67	**74**	69
551250001	Trout Lake Nursery	Vilas	61	60	63	61
551270005	Lake Geneva NADP Site	Walworth	**73**	67	**72**	70
551330027	Waukesha – Cleveland Ave.	Waukesha	67	66	67	66

Source: U.S. EPA AirData, Air Quality System (AQS): (http://www.epa.gov/air/data/index.html)

Figure 2.1: Certified 2014-2016 ozone design values (ppb).

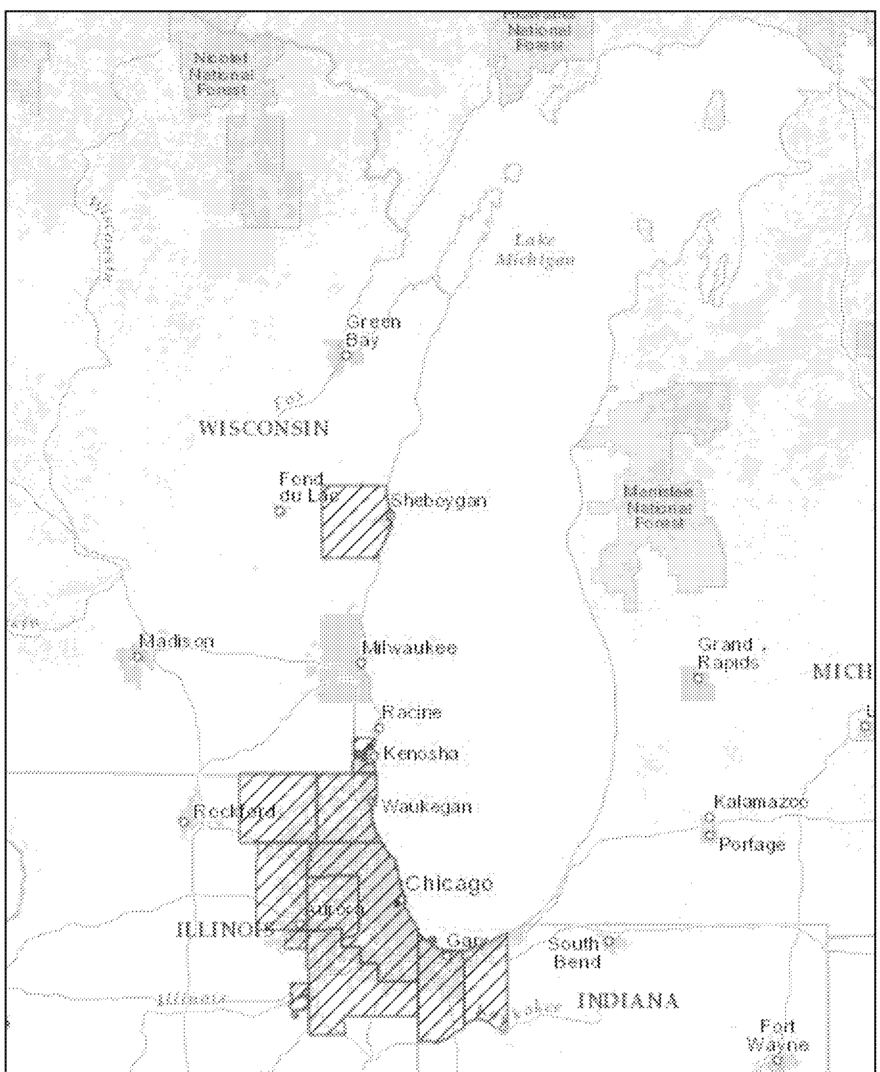


3. The Unique Ozone Dynamics of the Lake Michigan Region

3.1. Introduction

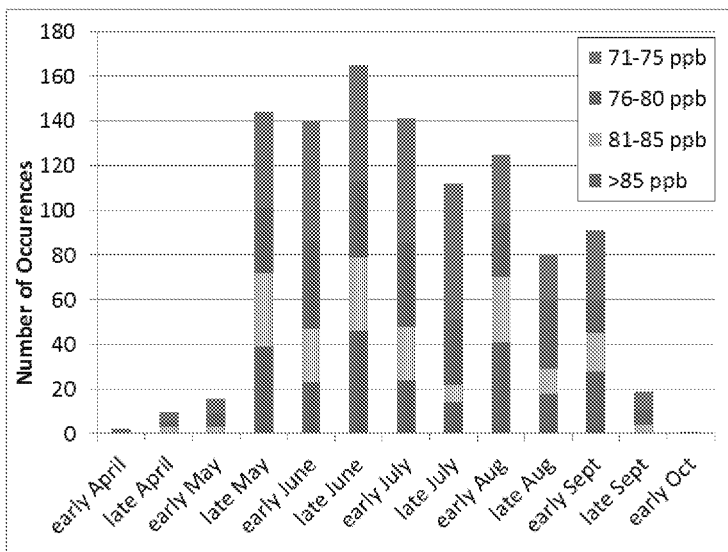
Monitors around Lake Michigan have a long history of ozone concentrations that exceed the level of the NAAQS. Since the promulgation of the original 1979 ozone NAAQS, lakeshore counties in Wisconsin, Illinois, Indiana and Michigan have been designated nonattainment with each subsequent standard. While ozone concentrations have decreased dramatically over time due to implementation of measures controlling ozone precursor emissions, there are still discrete areas with ozone concentrations above established NAAQS. For example, two Lake Michigan areas around Chicago, Illinois and Sheboygan County, Wisconsin (Figure 3.1) are currently designated nonattainment for the 2008 ozone NAAQS.

Figure 3.1. Map of the Lake Michigan region, with the Chicago and Sheboygan nonattainment areas for the 2008 ozone NAAQS indicated by hatching. (from LADCO)



Wisconsin's lakeshore monitors most frequently measure ozone concentrations exceeding the 2015 ozone NAAQS from late May through early August, with peak ozone exceedances in late June (Figure 3.2). A smaller number of exceedances occur in late August and early September with ozone concentrations rarely exceeding the 2015 ozone NAAQS before May 15 or after September 15. Ozone concentrations peak in the late spring and early summer because of the abundance of sunlight and heat, both of which contribute to ozone formation. In addition, strong land-lake temperature gradients in late spring and early summer cause lake breeze circulations that can contribute to high ozone concentrations, as discussed below.

Figure 3.2. Distribution of the number of occurrences of maximum daily 8-hour average ozone concentrations (MDA8) at monitors along Wisconsin's Lake Michigan lakeshore. Data are shown for the years 2005-2014.



The unique meteorology of the Lake Michigan area contributes strongly to the elevated ozone levels measured in this area. This meteorology causes transport of significant amounts of ozone from upwind sources to lakeshore counties in Wisconsin and neighboring states. Two types of meteorological patterns affect ozone concentrations in the region:

1) Synoptic scale meteorology[1] transports high concentrations of ozone and ozone precursors northward from source regions to the south and southeast, and
2) Mesoscale meteorology[1] (via land-lake breeze circulation patterns) carries precursors over the lake, where they react to form ozone. Winds then shift to pull the ozone onshore.

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[1] Synoptic-scale meteorology refers to weather features of 24-48 hours' duration, whereas mesoscale meteorology refers to weather features of shorter duration.

3.2. The Role of Synoptic-Scale Meteorology on High-Ozone Days

High pressure systems have been shown to generate meteorological conditions favorable to elevated ozone as they move through the eastern U.S. from west to east during late May to early September. These systems are typified by hazy, sunny skies with generally weak, clockwise-rotating winds and relatively shallow mixing such that near-surface pollution concentrations are not diluted by mixing. These meteorological conditions contribute to the buildup of ozone precursors and facilitate formation of ozone via photochemical reactions.

Ozone episodes are generally associated with high pressure systems over the eastern United States that transport pollutants and precursors from the south and east into the Lake Michigan region.[2,3] One study[4] estimated that 50 percent of Wisconsin's ozone exceedance days from 1980 to 1988 under the 1-hour ozone NAAQS occurred when the center of a high pressure system was situated southeast of the area (i.e., Ohio and east thereof). Under these circumstances, high ozone concentrations in the Lake Michigan region may result when polluted air from high emissions regions, such as the Ohio River Valley, is transported northward along the western side of a high pressure system.[5] In addition, while emissions from the heavily industrialized portions of the Lake Michigan region have decreased dramatically in recent decades, sources in large metropolitan areas along the lakeshore still generate ozone precursor emissions. Pollution from sources in these areas can add to the pool of pollution transported into the Lake Michigan region.[2]

Figure 3.3 shows the synoptic scale weather pattern for one such episode along with the resulting patterns in ozone concentrations. On this day a high pressure system was located to the southeast, centered over Virginia. Southeasterly to southerly winds on the western side of this system carried pollutants from the Ohio River Valley to Lake Michigan. This episode portrays a common pattern for ozone distributions on episode days: ozone concentrations were lowest in the regions with the highest emissions (in central Chicago and extending into northwestern Indiana) and the highest in rural coastal areas far downwind. During classic transport episodes such as this one, peak ozone concentrations move northward over the course of the day, carried by southerly winds. For example, on the day shown in Figure 3.3, ozone peaked at Wisconsin's southern Chiwaukee Prairie monitor between 11 a.m. and 1 p.m., at the Kohler Andrae monitor

[2] Dye, T.S., P.T. Roberts, and M.E. Korc, 1995: Observations of transport processes for ozone and ozone precursors during the 1991 Lake Michigan Ozone Study. J. App. Meteor, 34: 1877-1889.

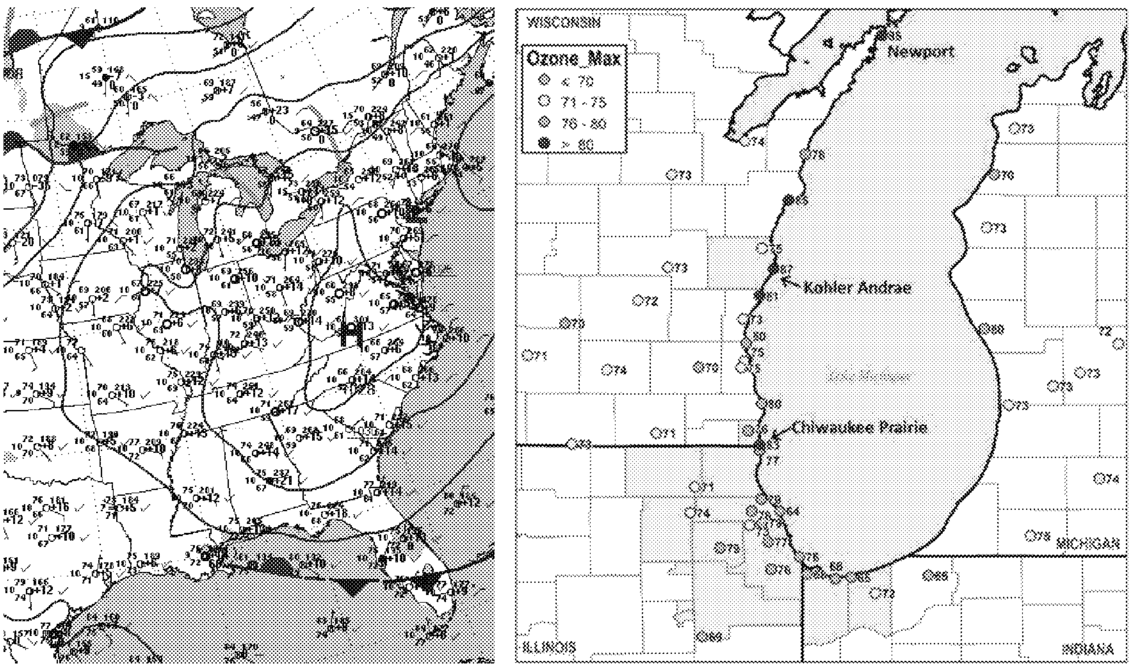
[3] Hanna, S.R., and J.C. Chang, 1995: Relations between meteorology and ozone in the Lake Michigan region. J. Applied Meteorology, 34: 670-678.

[4] Haney, J.L., S.G. Douglas, L.R. Chinkin, D.R. Souten, C.S.Burton, and P.T. Roberts, 1989: Ozone Air Quality Scoping Study for the Lower Lake Michigan Air Quality Region, SAI report #SYSAPP-89/101, prepared for US EPA, August, 197 pp.

[5] For example, Ragland, K. and P. Samson, 1977: Ozone and visibility reduction in the Midwest: evidence for large-scale transport. J. Applied Meteorology, 16: 1101–1106.

midway up the coast between 2 p.m. and 4 p.m., and at the northern Newport monitor between 4 p.m. and 6 p.m.

Figure 3.3. Surface synoptic weather map for 6 a.m. CST for the eastern U.S. (left), and the maximum daily 8-hour average (MDA8) ozone concentrations for the Lake Michigan region (right) for June 19, 2016. The Chicago and Sheboygan ozone nonattainment areas are shaded in gray.



3.3. The Role of Mesoscale Meteorology (Lake Breeze Circulation) on High-Ozone Days

Synoptic meteorological conditions often work in combination with unique lake-induced mesoscale meteorological features to produce the highest ozone concentrations in this region. Historically, Wisconsin's ozone nonattainment areas have been positioned along the state's Lake Michigan shoreline (Figure 3.1). With a surface area of approximately 22,400 square miles, Lake Michigan acts as a large heat sink during the warm months. Figure 3.4 highlights the considerable difference between the over-land air temperatures (measured at Racine, Wisconsin) and overwater air temperatures (measured at a buoy in southern Lake Michigan) during a 5-day ozone episode in June 2002. The strong daytime temperature contrast between the warm land and cold lake can lead to the formation of a thermally-driven circulation cell called the "lake breeze", which runs approximately perpendicular to the Lake Michigan shoreline (Figure 3.5).

As this figure shows, the lake breeze is generally preceded by an early morning land breeze, driven by relatively warm temperatures over the lake. The land breeze can carry ozone precursors emitted from urban areas, primarily Chicago, out over the lake, where they can react to form ozone. The onshore flow of the lake breeze circulation then transports elevated ozone from over the lake into eastern Wisconsin.

Figure 3.4. Hourly surface air temperatures at Racine, WI and at the South Lake Michigan Buoy during an ozone episode on June 20-25, 2002.

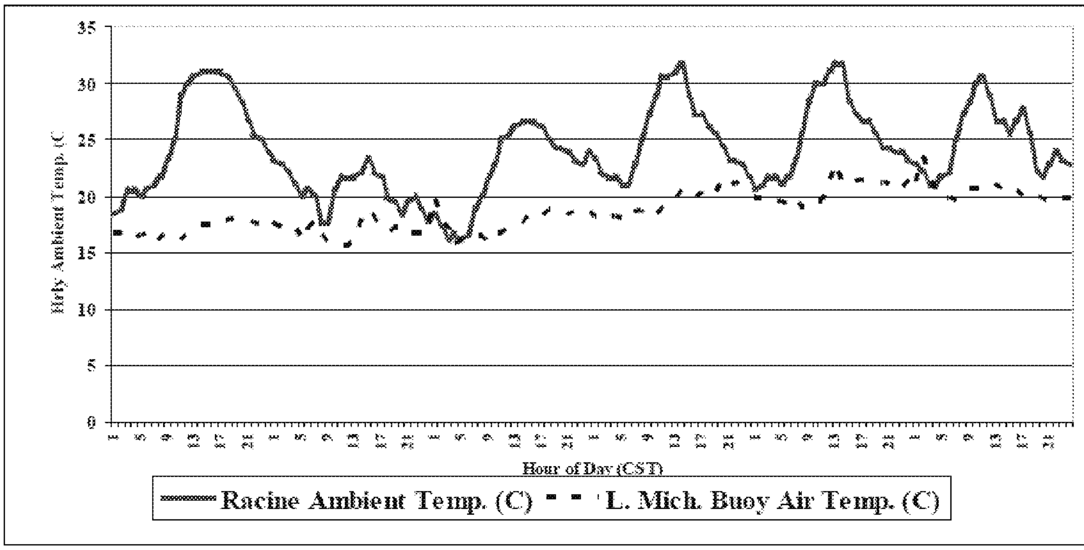
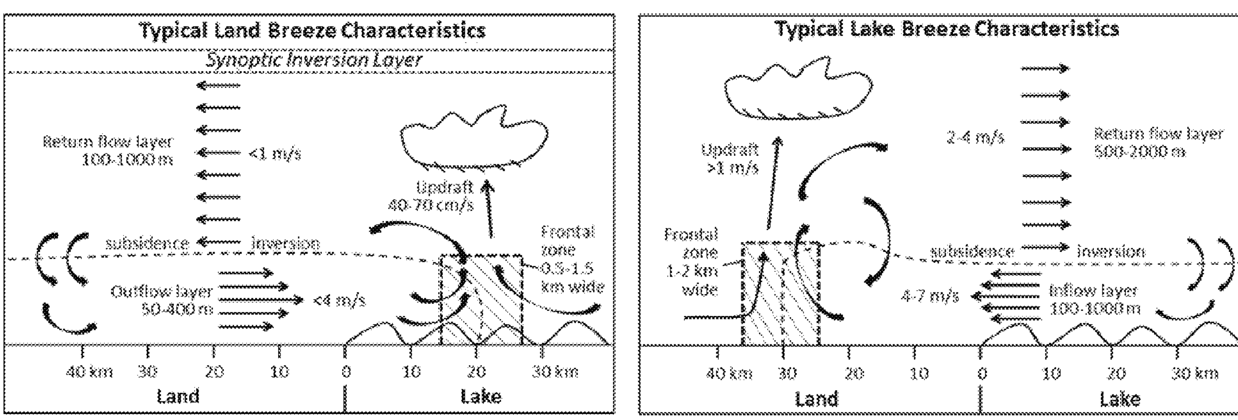


Figure 3.5. Schematic diagrams of the early morning land breeze (left) and late morning/afternoon lake breeze (right) circulations responsible for enhanced ozone production along the Lake Michigan shoreline. (modified from Foley et al., 2011[6])



3.4. Conceptual Model for Ozone Formation in the Lake Michigan Region

Synoptic and mesoscale meteorological patterns together drive ozone formation in the region, as described in a conceptual model in Dye et al. (1995).[2] Dye et al. (1995) described this model with a series of inter-related steps. These steps are described below, focusing on the conditions impacting Wisconsin's shoreline:

[6] Foley, T., E. A. Betterton, P.E. R. Jacko, and J. Hillery, 2011: Lake Michigan air quality: The 1994-2003 LADCO Aircraft Project (LAP), Atmos. Env., 45: 3192-3202.

1) A shallow but intensely stable conduction inversion exists just above the relatively cold lake surface (Figure 3.5). During the early morning hours the land breeze and general offshore flow (i.e., southerly to west-southwesterly winds) transport ozone and fresh precursor emissions into the stable air in the conduction layer over Lake Michigan. A primary source region is the Chicago area, located at the southern edge of the lake.

2) By midmorning a sharp horizontal temperature gradient forms along the shoreline between the cold lake air and the increasingly warmer air over the land. This gradient effectively "cuts off" air in the conduction layer from additional injections of shore-emitted precursors. Strong stability in the conduction layer limits dispersion, creating high concentrations of ozone precursors, which can react in this layer.

3) By midmorning, the developing convective boundary layer (CBL) grows and the resulting convection mixes ozone vertically, where it combines with ozone transported from sources outside the region. Ozone concentrations in this air are lower due to the dilutive effects of convective mixing. As this air is transported towards the lake, it is forced to flow up and over the conduction layer (Figure 3.5).

4) The ozone-rich air in both layers is transported northward over Lake Michigan by the prevailing winds. When a lake breeze is present, it produces southerly to south-southeasterly winds along the western shore of Lake Michigan. This wind pattern transports the ozone originating from sources in the south to downwind receptor regions along the eastern Wisconsin lakeshore. On occasion, areas north of Ozaukee County experience elevated ozone levels as a southerly wind intercepts the shoreline where it juts into Lake Michigan.

5) When the ozone-laden air flows onshore in the downwind receptor regions, air with the highest ozone concentrations, located in the lowest 300 meters, mixes with the air at ground level along the shoreline. This causes the highest ozone concentrations to be found along the shoreline. Eventually, air from higher altitudes mixes with air at ground level further inland. This air mass is the remnant of the ozone-diluted CBL air that flowed up and over the conduction layer during the mid-morning hours, which is why ozone concentrations are lower further inland.

This complex meteorology leads to the high ozone concentrations and persistent nonattainment issues faced by the counties along the Lake Michigan shoreline.

4. Evidence of Narrow Ozone Concentration Gradients Along the Wisconsin Lakeshore

The conceptual model presented in Chapter 3 indicates that ozone concentrations in Wisconsin should be highest near Lake Michigan and decrease away from the lakeshore. This chapter presents a number of analyses that confirm that narrow and steep gradients in ozone concentrations exist along Wisconsin's Lake Michigan shoreline during ozone episodes. These analyses also suggest that the origins of ozone measured inland differ from the ozone impacting the lakeshore.

To determine the extent and nature of this lakeshore ozone gradient, this chapter examines evidence from two primary sources: (1) photochemical modeling results, and (2) ozone data from monitors located in lakeshore counties. This analysis also highlights the central role of lake breeze events in creating the sharp concentration gradients observed along the lakeshore.

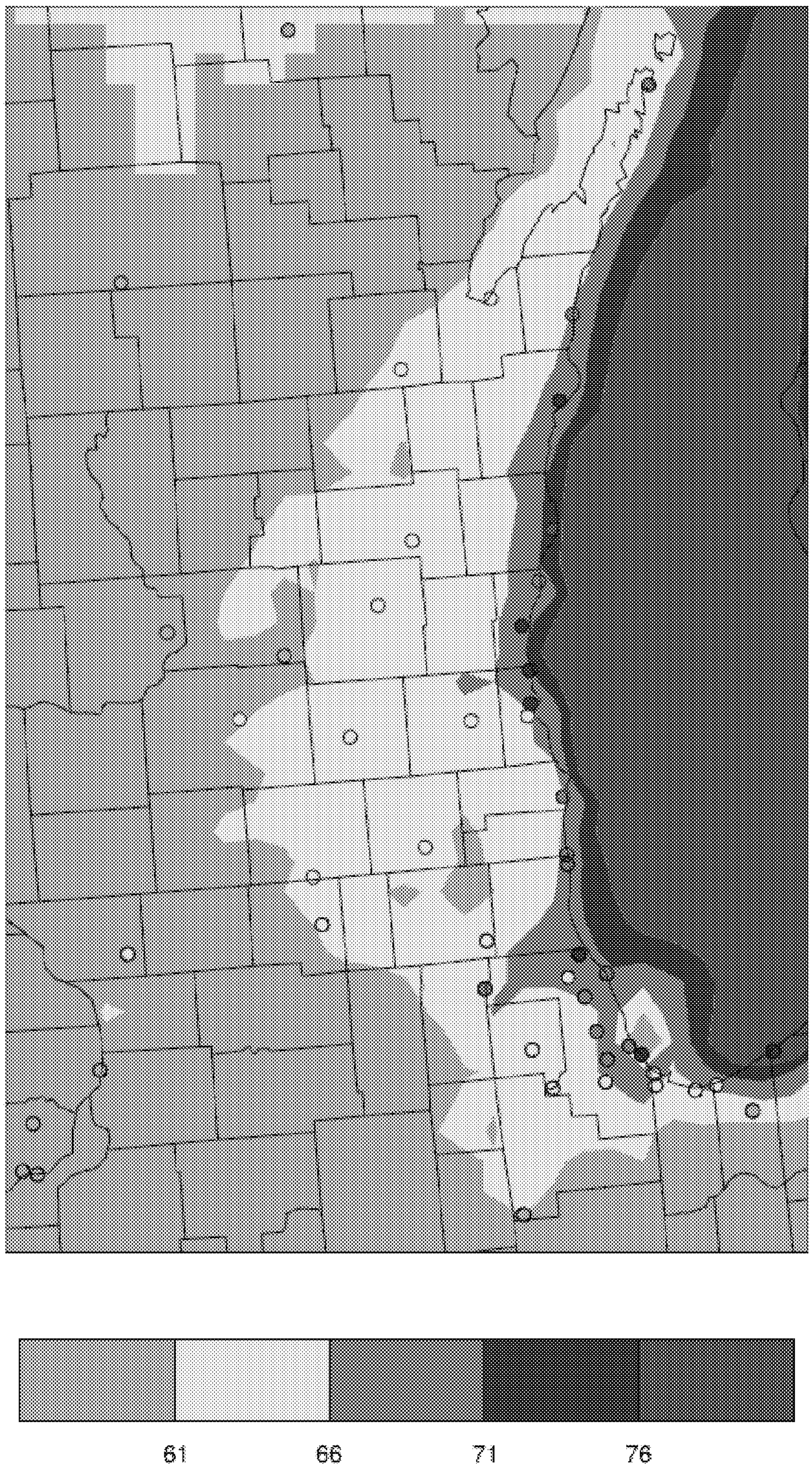
4.1. Photochemical Modeling Results

Recent photochemical modeling conducted by the Lake Michigan Air Directors Consortium (LADCO) indicates there is a steep, consistent ozone concentration gradient along the entire Lake Michigan lakeshore (Figure 4.1).[7] This modeling strongly suggests that high ozone design values are confined to a very narrow band that follows the shape of the lakeshore along most of the Wisconsin shoreline.

This modeling projects that the highest design values (≥76 ppb) remain almost exclusively over Lake Michigan. Concentrations of 71 to 75 ppb reach the shoreline in some places, but never penetrate deeply. Because this figure is based on model projections of ozone concentrations rather than actual measurements, the exact concentrations shown are illustrative only.[8] However, the gradients projected by the model are informative as they show how elevated ozone levels drop off dramatically in Wisconsin as distance from the lake increases. The remainder of this section examines monitoring data that lends support to this conclusion.

[7] This modeling is based on emissions estimates for 2017 and base year 2011 meteorology.
[8] These modeling results tend to underpredict ozone concentrations relative to the 2014-2016 design values.

Figure 4.1. Photochemical model projections of 2017 design values along the western Lake Michigan shoreline. Design values are shown in ppb. Monitor values shown are projections from the model attainment test software for the grid cell containing the monitor. The modeling was completed by LADCO.



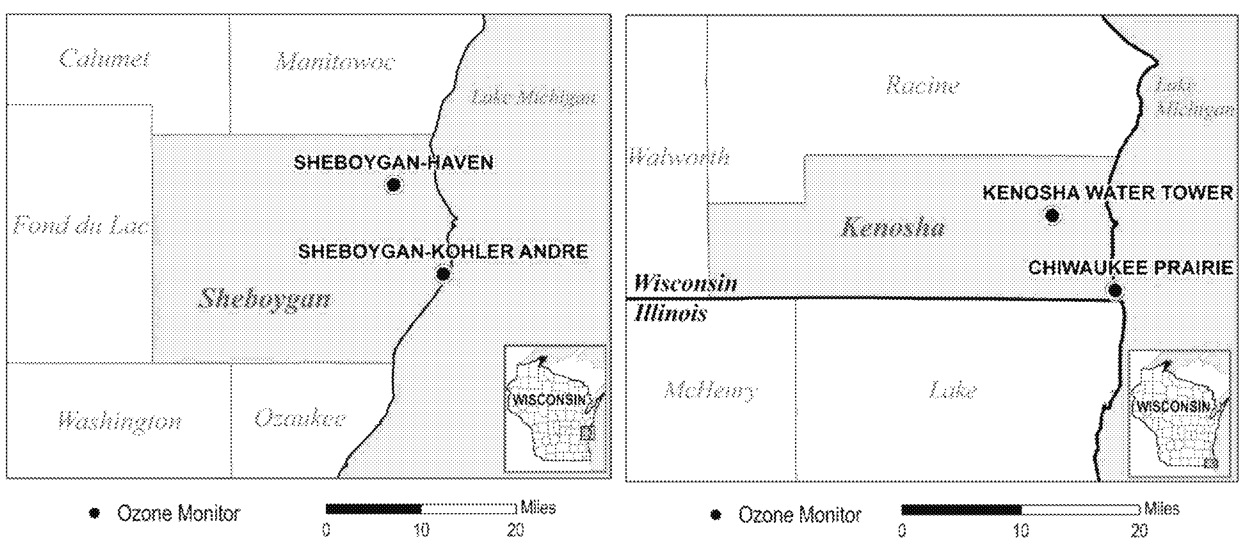
4.2. Comparing Data From Inland and Lakeshore Monitors

The photochemical modeling suggests that the air quality in the inland portions of the lakeshore counties contains lower levels of ozone than the areas nearest to Lake Michigan. Analysis of data from monitors operating inland and along the lakeshore provides new insight into the actual spatial distribution of ozone concentrations along Wisconsin's Lake Michigan shoreline.

The two monitors that usually measure the highest ozone concentrations in Wisconsin, Sheboygan County's Kohler Andrae monitor and Kenosha County's Chiwaukee Prairie monitor, are both located within several hundred feet of the Lake Michigan shoreline. For the last several years, WDNR has operated additional monitors located a few miles inland from these monitors (Figure 4.2):

- The Kenosha Water Tower monitor began operating in 2013. It is located 7.4 miles northwest of the Chiwaukee Prairie monitor and 3.6 miles inland from Lake Michigan.
- The Sheboygan Haven monitor began operating in 2014. It is located 10.9 miles north-northwest of the Kohler Andrae monitor and 3.2 miles from the lakeshore.

Figure 4.2. Location of the inland and lakeshore ozone monitors in Sheboygan (left) and Kenosha (right) counties.



4.2.1. Analysis of 8-Hour Average Data

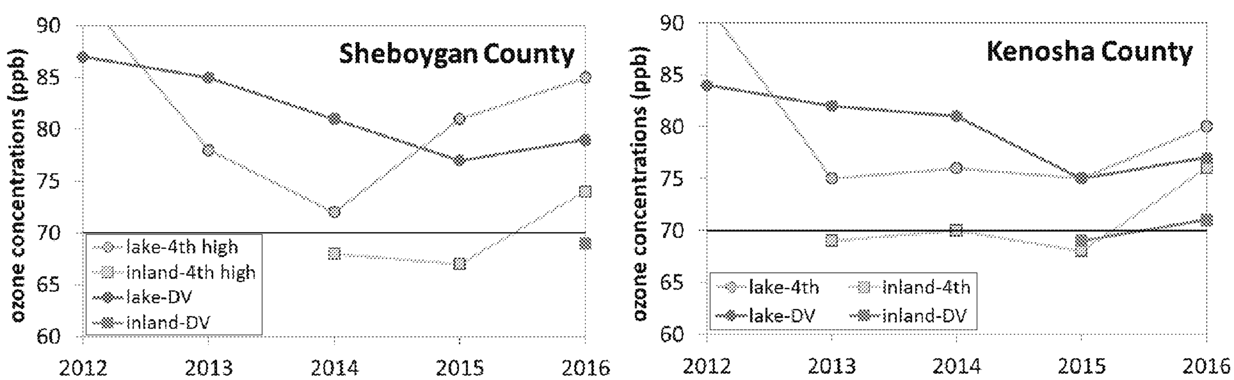
Figure 4.3 shows that, for the years that data from both monitors are available, the fourth high MDA8 ozone concentrations at the inland monitors were substantially and consistently lower than those recorded at the lakeshore monitors:

- In Sheboygan County, the fourth high MDA8 values at the inland monitor were 4 to 14 ppb lower than those at the lakeshore monitor.
- In Kenosha County, these values were 4 to 7 ppb lower at the inland monitor when compared to the lakeshore monitor.

Note that a measurable and meaningful difference in measurements between the monitors was found each year, so this difference is not the result of an unusual year. This data confirms that measured ozone concentrations consistently and sharply decrease away from the lakeshore in these two counties. This is also consistent with the photochemical modeling results described in section 4.1.

These differences are likewise reflected in design values at these monitors. The 2014-2016 design value for the inland Sheboygan Haven monitor is 69 ppb – this is below the level of the 2015 ozone NAAQS and 10 ppb lower than the design value for the Kohler Andrae monitor. The 2014-2016 design value for the Kenosha Water Tower monitor was 71 ppb, which is 6 ppb lower than the design value for the Chiwaukee Prairie monitor. This confirms the steep drop-off of concentrations within the lakeshore ozone gradient.

Figure 4.3. Trends in annual fourth high maximum daily 8-hour average concentrations and design values for both monitors in Sheboygan (left) and Kenosha (right) counties.



4.2.2. <u>Analysis of Hourly Data</u>

Examination of the hourly ozone concentrations at these two locations provides additional insights into the patterns of ozone concentrations near the lakeshore. Figure 4.4 shows the 1-hour average ozone concentrations for the Kohler Andrae and Sheboygan Haven monitors over the course of a 5-day ozone episode in 2014. Three days in this episode resulted in MDA8 values over 70 ppb at the Kohler Andrae monitor and one day resulted in an MDA8 value over 70 ppb at the Sheboygan Haven monitor. This ozone episode is typical of the episodes that affect the lakeshore and offers an excellent example of how ozone concentrations compare at the two monitors located in Sheboygan County.

Figure 4.4. Hourly ozone concentrations at the Sheboygan County lakeshore (Kohler Andrae) and inland (Sheboygan Haven) monitors for an episode in July 2014. The maximum daily 8-hour average (MDA8) ozone concentrations for each site are listed at the bottom of the figure, color-coded by monitor.

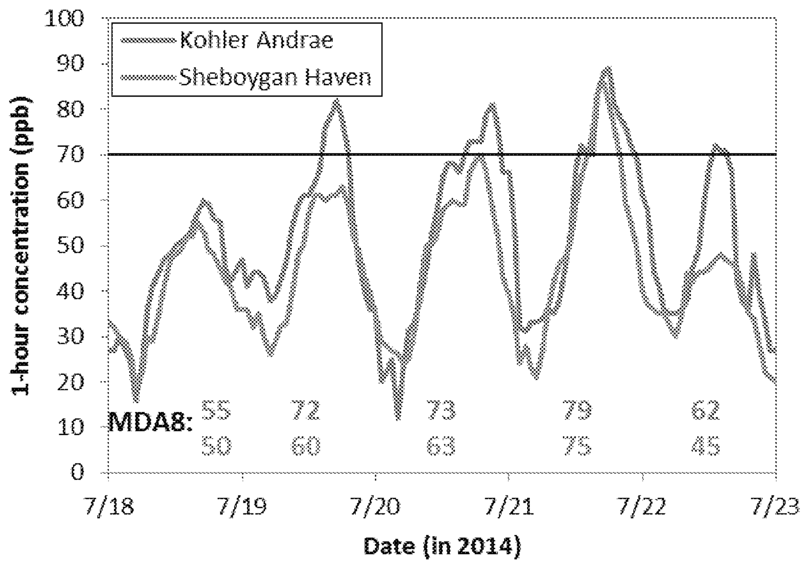
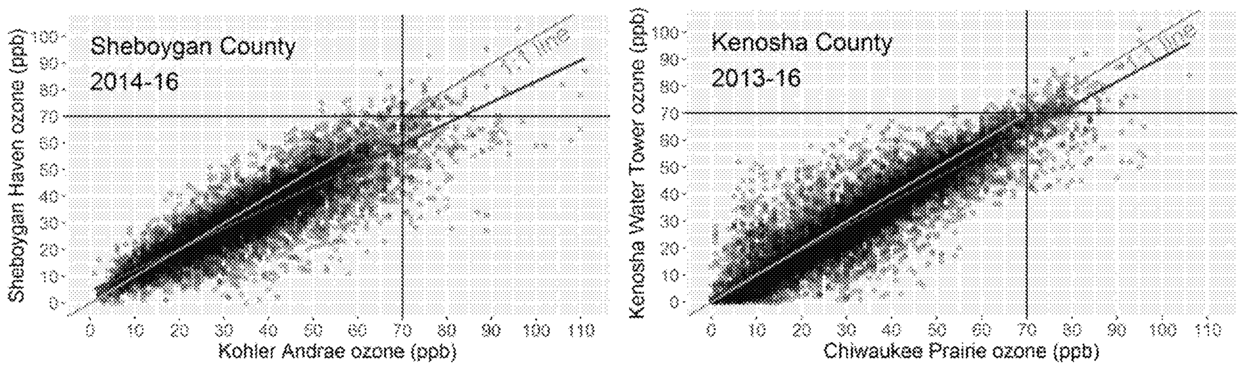


Figure 4.4 shows that hourly ozone concentrations generally changed at both sites in parallel. However, 1-hour concentrations at the lakeshore Kohler Andrae monitor were almost always higher than those at the inland Haven monitor. Peak differences were also consistently higher at the lakeshore monitor – as much as 20 ppb higher on July 19 and 22.[9] Overall, this episode shows systematic differences between inland and lakeshore ozone concentrations that are consistent with the differences observed in fourth high MDA8 and design values.

Figure 4.5 contains an analysis of all 1-hour ozone concentrations at these inland and lakeshore monitors. This data shows that the same trends observed during the 2014 episode were also present more generally; that is, 1-hour ozone concentrations at both inland monitors showed a consistent pattern of being lower than those monitored at the lakeshore. This is evident from the fact that most hourly concentrations are below the blue 1:1 line shown on the figures.[10] In addition, this data shows that these concentration differences were greatest when lakeshore ozone concentrations were at their highest. These inland-lakeshore concentration differences also tend to be greater in Sheboygan County relative to Kenosha County.[11]

[9] Section 4.2 discusses the differences in ozone transport inland under different meteorological conditions in some depth.
[10] The blue 1:1 line shows the relationship if the inland and lakeshore monitors had the same ozone concentration values.
[11] The same trends are found with MDA8 values (not shown).

Figure 4.5. Scatterplots of 1-hour ozone concentrations comparing inland monitors to lakeshore monitors in Sheboygan and Kenosha counties. The blue lines show the 1:1 line, and the red lines show the best-fit line to the data.



Appendix C contains additional analyses of this 1-hour ozone data. Most notably, these analyses find that during hours when lakeshore ozone was above 70 ppb, inland concentrations were consistently much lower. For example, during the 24 hours when lakeshore ozone concentrations were greater than 90 ppb in Sheboygan County, the median inland concentration was only 66 ppb. These findings conclusively demonstrate that the highest ozone concentrations are confined to the lakeshore monitors.

4.2.3. Conclusions

This data indicates that air with ozone concentrations above the level of the 2015 ozone NAAQS rarely reaches the inland monitors in Sheboygan and Kenosha Counties. Specifically, it shows that the highest-ozone air is confined to a band less than 3.6 miles wide along the lakeshore during most high-ozone episodes. The air located to the west (inland) of this lakeshore band has significantly lower average ozone concentrations during these episodes. The finding of similar results for both Sheboygan and Kenosha Counties, despite their different locations and geographies[12], indicates that this pattern is likely to hold for most of Wisconsin's Lake Michigan shoreline. Chapter 5 includes additional analyses of ozone concentrations under different meteorological conditions that further support this conclusion.

These results indicate that, if EPA elects to impose ozone nonattainment areas on Wisconsin, these areas should be no more than a few miles wide and should conform to the shape of the coastline. Further comparisons of the inland and lakeshore monitors are used in Chapter 6 to calculate the location of the 70 ppb contour along the lakeshore.

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[12] These counties are located roughly 80 miles away from each other in different parts of the Wisconsin lakeshore and also have different coastline shapes, with Sheboygan County extending into the lake whereas Kenosha County has a relatively straight south-north configuration.

4.3. Analysis of the Lake Breeze Phenomenon

As described in Chapter 3, the lake breeze has been shown to play an important role in delivering high-ozone air to lakeshore monitors. This section examines the impact of lake breeze events on ozone concentrations at the inland and lakeshore monitors in Sheboygan and Kenosha Counties. This analysis confirms the steep concentration gradients observed in the previous section and helps explain their origin. It also helps define the unique ways in which the mesoscale meteorology of the Lake Michigan region drives ozone distribution along Wisconsin's Lake Michigan shoreline.[13]

This analysis used wind direction data and satellite images to classify days with peak 1-hour ozone concentrations above 70 ppb into one of three event types:[14]

- "Deep" lake breeze, meaning a day on which the lake breeze affected both the lakeshore and inland monitors.
- "Shallow" lake breeze, meaning a day on which the lake breeze affected the lakeshore but not the inland monitor.
- No lake breeze, meaning a day with no apparent lake breeze.

A small number of days were not able to be classified according to the event types above because of complex patterns. Classification of high-ozone days into these categories yielded the distribution of event types shown in Table 4.1. On most high-ozone days, the lake breeze reached the inland monitor.

Table 4.1. Distribution of the occurrence of different types of lake breeze events at the Sheboygan and Kenosha county monitors. The percentage of the classifiable events (which excludes "unclear" events) in each category is shown in parentheses.

	Deep lake breeze	Shallow lake breeze	No lake breeze	Unclear	Total days
Sheboygan	33 (67%)	5 (10%)	11 (22%)	8	57 (2014-16)
Kenosha	45 (62%)	13 (18%)	15 (20%)	8	81 (2013-16)

Peak 1-hour ozone concentration data for different lake breeze types are shown in Figure 4.6. This data shows that, while median peak ozone concentrations at the lakeshore were similar across all event types, median peak concentrations at inland monitors were considerably lower.

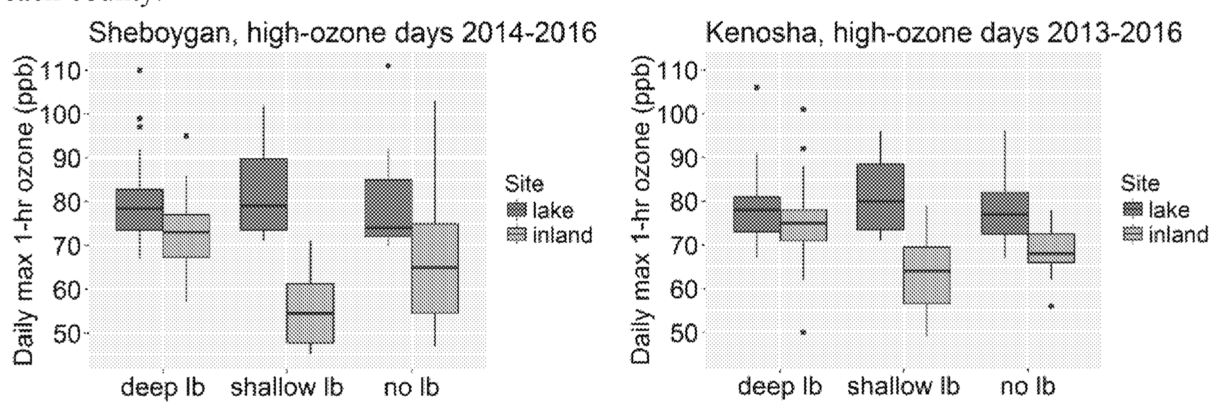
[13] Chapter 5 examines the ways in which interstate transport driven by synoptic-scale meteorology affects ozone in this region.

[14] Deep and shallow lake breezes were identified based on the occurrence of wind shifts to directions characteristic of lake breezes at the monitors. These classifications were confirmed by examination of MODIS satellite images that can show the presence of lake breeze fronts if the right type of clouds is present. See Appendix C for more information.

The inland-lakeshore concentration differences were especially large during shallow lake breeze events. Even during deep lake breeze events (when the lake breeze reached the inland monitor), peak concentrations at the inland monitor were on average 5 ppb lower than at the lakeshore monitor in Sheboygan and 3 ppb lower in Kenosha.[15] This result is consistent with the conceptual model for ozone formation in this region presented in Section 3.4.

Analysis of this data for individual days (see Appendix C) indicates that direct overland transport of ozone from the Chicago area also can affect concentrations measured at the inland Kenosha County monitor. This effect is most clearly evident on some days with deep[16] or shallow lake breezes. These days had hot temperatures (reaching 85-90°F at the Kenosha Water Tower monitor) and southerly to southwesterly winds that transported ozone-rich air from Chicago area sources into southeast Wisconsin. In 2016, direct overland transport of ozone was observed during the days with the highest and fourth highest MDA8 values, indicating that this mechanism can have an important impact on ozone design values at the inland Kenosha Water Tower monitor. There is no evidence from the data that any direct, overland transport occurred at the inland Sheboygan monitor.

Figure 4.6. Boxplots for Sheboygan and Kenosha counties showing the median and range[17] of daily maximum 1-hour average ozone concentrations for ozone episodes with deep, shallow, and no lake breeze ("lb"). Data are shown for the lakeshore and inland monitors in each county.



[15] Appendix C includes additional analyses of this data, including average profiles of ozone concentrations and wind direction for each type of high-ozone event.

[16] On days with a deep lake breeze, direct overland transport occurred in the hours before the lake breeze reached the inland monitor.

[17] Boxplots show the median and range of inland concentrations observed for a bin of lakeshore concentrations. The line in the middle of the box shows the median concentration, and the box encloses the middle half of the concentrations (e.g., the 25th to the 75th percentile values). The "whiskers" extend to the highest or lowest value within 1.5 times the interquartile mean (the difference between the 25th and 75th percentile values) beyond the box. The points are outliers that fall beyond the whiskers.

This data shows that, while lake breezes usually reach the inland monitors, the ozone concentrations carried by these lake breezes decrease sharply as they move inland. For example, during deep lake breeze events in Sheboygan, peak ozone concentrations decreased by roughly 5 ppb over 3.2 miles. In Kenosha, average peak ozone concentrations dropped by roughly 3 ppb in 3.45 miles.[18] This magnitude of difference helps explain the differences observed in the 8-hour ozone design values at these monitors.

In addition, this analysis shows that some lake breeze events don't reach the inland monitors at all. The concentration gradients during these shallow lake breeze events are even more pronounced, decreasing around 25 ppb in just 3.2 miles (in the case of the Sheboygan monitors) and 15 ppb in 3.45 miles (at the Kenosha monitors).

This analysis concludes that the steep ozone gradients found along the lakeshore result from the lake breeze phenomenon. The steepness of the ozone concentration gradient depends on the type of lake breeze event. This analysis also shows that, in addition to the lake breeze, direct overland transport of ozone influences concentrations measured at the inland Kenosha monitor, but does not appear to affect ozone concentrations at either Sheboygan monitor. This information will be used in Chapter 6 to define the 70 ppb ozone design value contour along the Wisconsin lakeshore.

4.4. Conclusions

The analyses in this chapter, which draw upon the latest data and modeling, demonstrate conclusively that ozone concentrations drop off dramatically and consistently within a few miles of Lake Michigan. This work also presents some insight into the characteristics of these gradients and the mechanisms that create them. In particular:

- Ozone design values were 6-10 ppb lower at the inland monitors compared with lakeshore monitors located in the same county.
- Average hourly ozone concentrations remained low at the inland monitors (located just 3.2 to 3.6 miles inland) during high-ozone hours, even when lakeshore concentrations exceeded 90 ppb.
- Meaningful ozone concentration differences between monitors were present even when the lake breeze reached the inland monitor.
- The gradients in measured ozone were especially steep during shallow lake breeze events, when the ozone-rich air from over the lake didn't reach the inland monitors.

These analyses demonstrate that the highest ozone concentrations are predominantly confined to a narrow strip of land that follows the Lake Michigan shoreline. Inland portions of the lakeshore

[18] The lakeshore Chiwaukee Prairie monitor is located 0.15 miles from the shoreline, so the inland distance between the two monitors is 3.45 miles.

counties experience much lower ozone concentrations under all ozone episode types; these areas, as well as those areas further west, are highly unlikely to regularly measure ozone concentrations exceeding 70 ppb. This is critically important information when considering 2015 ozone NAAQS designations.

5. The Origins of High-Ozone Air Along the Wisconsin Lakeshore

This chapter examines the sources of the ozone-rich air impacting Wisconsin's Lake Michigan lakeshore using a number of types of analyses including the use of wind direction analysis and HYSPLIT back trajectories to examine the paths of transported ozone during ozone episodes; source apportionment modeling to estimate the contribution of ozone from different regions to monitors located both along the lakeshore and inland; and photochemical modeling of emissions reduction scenarios to examine how much control Wisconsin has on ozone concentrations along its lakeshore. These analyses demonstrate that interstate transport of ozone leaves the state with little ability to reduce ozone concentrations within its own borders. This chapter also shows that air at inland monitors may have different origins than air at lakeshore monitors, confirming earlier work showing differences between these monitors.

5.1. The Impact of Transport on Lakeshore Ozone Concentrations

This section uses several approaches to illustrate the impact of ozone transport on ozone concentrations measured along Wisconsin's lakeshore. The first approach examines the wind directions that deliver ozone-rich air to monitors in the region. The second approach analyzes the back trajectories of air parcels during ozone episodes to examine where these air parcels might have acquired their ozone. The final approach uses source apportionment modeling to describe the impact of transported ozone to concentrations measured at these monitors.

5.1.1. Analysis of Air Pollution Roses

The importance of transport in delivering ozone-rich air to monitors along Wisconsin's Lake Michigan lakeshore is evident from analysis of the wind directions from which this air originates. Figure 5.1 shows "air pollution roses" for all Lake Michigan monitors in Wisconsin that collect both wind direction and ozone concentration data.[19] This analysis shows that, in all cases, ozone concentrations measuring in excess of 70 ppb are being delivered to the monitors from over Lake Michigan. If local emissions were contributing to elevated ozone levels at these monitors, the pollution roses would instead show significant additional contributions from over land.

[19] The Kewaunee, Bayside, and Racine Payne and Dolan monitors do not collect wind data.

Figure 5.1. Ozone pollution roses for hours with ozone above 70 ppb (left) and maps of monitor locations for lakeshore monitors (right). In the pollution roses, the length of the paddle shows the percentage of hours with winds from that direction, and the color corresponds to the average ozone concentration during those hours. The blue line in both figures shows an estimate of the shoreline angle, and the red arrow shows the angle of the dominant wind direction at that monitor. Map scales vary somewhat between maps.

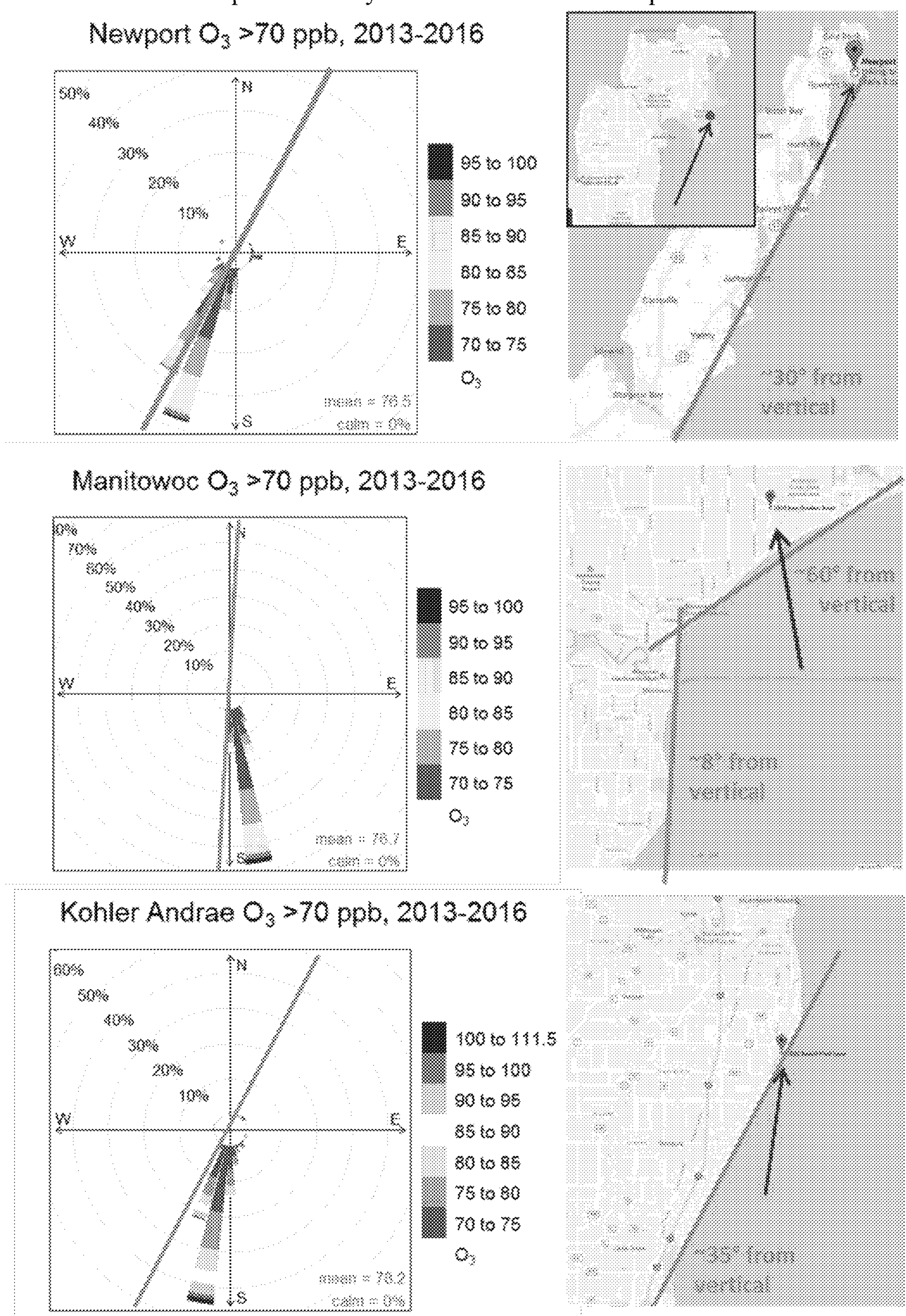


Figure 5.1. (continued)

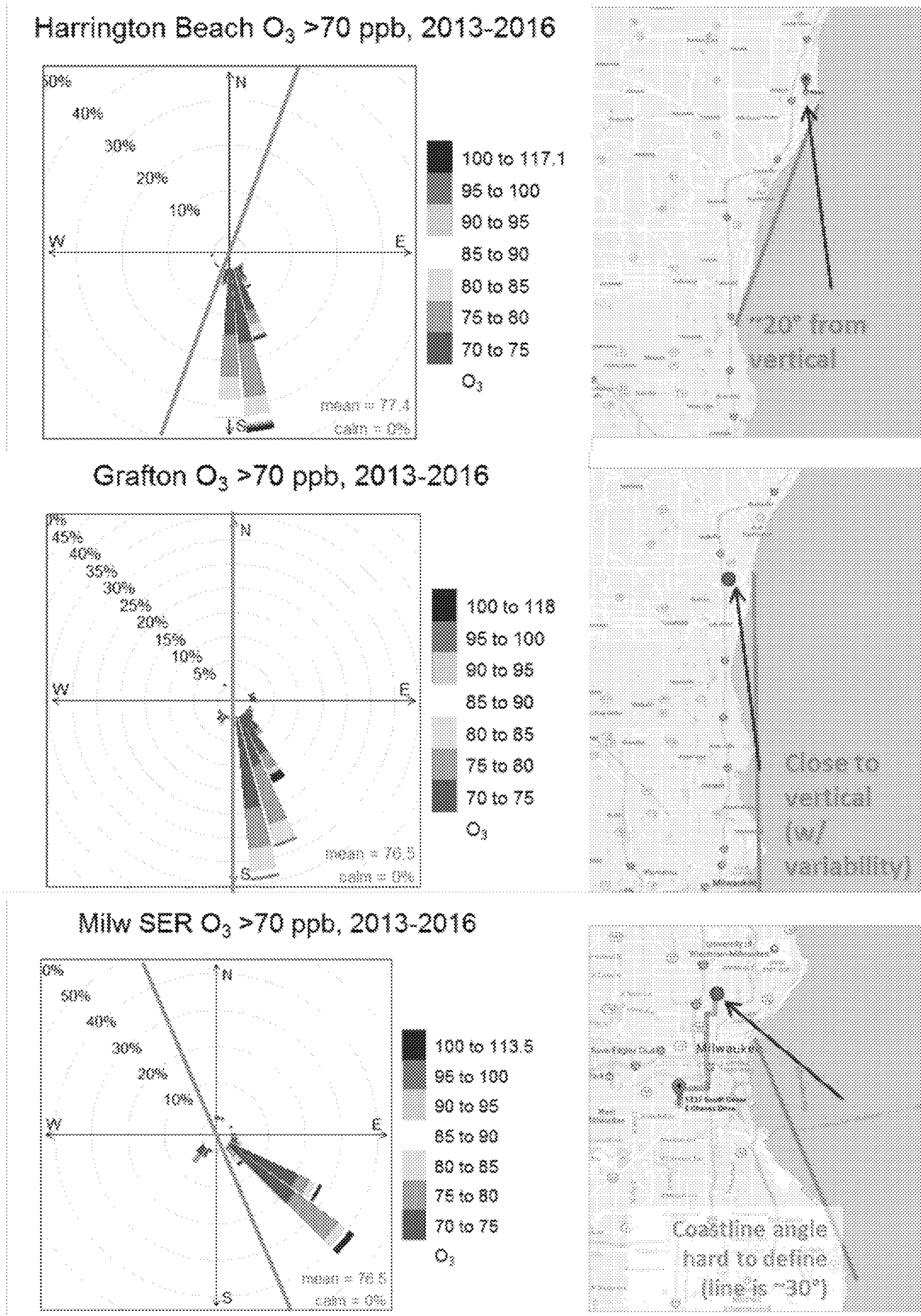
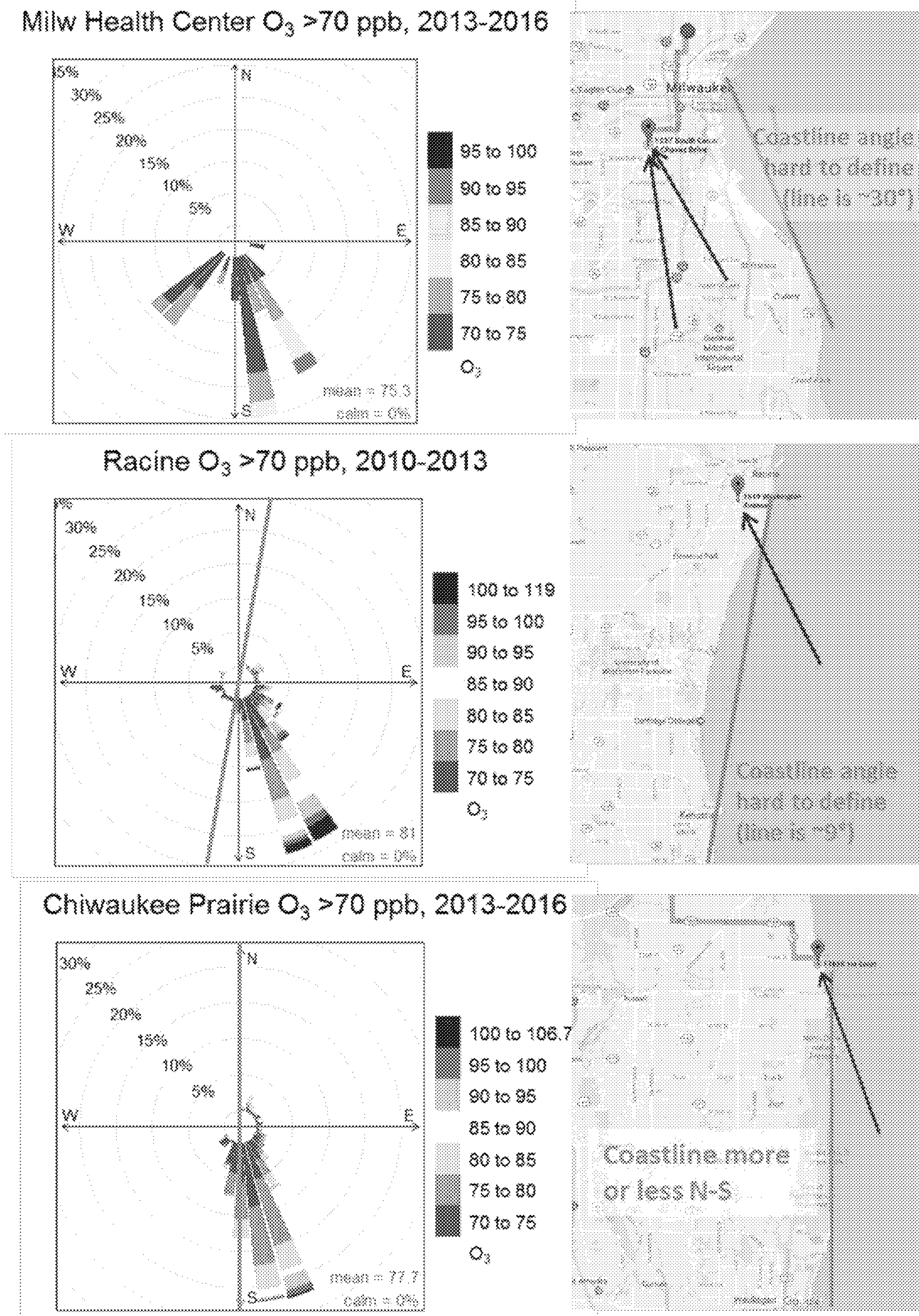


Figure 5.1. (continued)*



*Wind data is not collected at the currently operating Racine Payne and Dolan monitor, so the Racine pollution rose plots data from the old Racine monitor for the years 2010-2013.

For all Wisconsin lakeshore monitors, the dominant wind directions carrying ozone concentrations greater than 70 ppb come from the east (i.e., over the lake) relative to the shoreline.[20] The southernmost monitor, Chiwaukee Prairie, also receives some ozone-rich air from the south-southwest; this is most likely directly transported from the Chicago area. Such overland transport, however, is not apparent at the next most southerly monitor (in Racine), demonstrating the importance of winds that travel over Lake Michigan in delivering ozone to Wisconsin's lakeshore. It also underscores the importance of transport of ozone from the south to these monitors. The data from pollution roses are in line with the predictions of the conceptual model (outlined in Chapter 3).

Figure 5.2 shows air pollution roses for several inland monitors (Sheboygan Haven, Kenosha Water Tower, Waukesha, and Lake Geneva). Comparing this data with that for the lakeshore counties shows that the dominant ozone-laden winds come from a slightly more easterly direction at the inland monitors. The Kenosha Water Tower (WT) monitor also receives ozone-enriched air from the southwest. This air is likely transported directly over land from the Chicago area to the south and southwest. Such direct transport was found on a subset of lake breeze event days, as discussed in section 4.3, and is also evident at the Chiwaukee Prairie monitor.

The monitors in Waukesha and Walworth counties were also evaluated. These monitors receive most of their ozone-laden air from the southeast (for Waukesha) or east-southeast (for Lake Geneva). Ozone concentrations are low in Waukesha relative to the lakeshore monitors, most likely because of this site's distance from the shoreline and because major source regions do not lie directly upwind during high-ozone hours.[21] The air pollution rose suggests that winds reaching Lake Geneva on high ozone days passed through the northern Chicago suburbs. These winds likely carried significant ozone from the Chicago region over land to the Lake Geneva monitor. Overall, it is clear that transport from the south, both directly and via the lake breeze, is the major source of ozone to these inland monitors.

In summary, these air pollution roses show that high-ozone air almost always arrives at Wisconsin's lakeshore monitors from the south over Lake Michigan, indicating that transported ozone, rather than local or nearby emissions, is driving the high ozone values at these locations. Ozone delivered to inland monitors is also influenced by the direct transport of ozone overland from the greater Chicago area. This overland transport may carry ozone-rich air slightly farther inland in Kenosha County than the lakeshore counties more distant from Chicago.

[20] Note that the coastline angle seems to be less important for the Milwaukee Health Center monitor, which has complex ozone-delivering wind patterns and generally very low ozone concentrations. The air travels many miles overland before reaching this monitor, so this monitor likely falls in a different category than the others.
[21] Racine County is upwind of the Waukesha monitor on high-ozone days. As discussed previously, ozone-rich air is diluted as it moves inland and mixes with cleaner air or reacts with surfaces, leading to lower concentrations inland relative to the lakeshore.

Figure 5.2. **Ozone pollution roses for hours with ozone above 70 ppb (left) and maps of monitor locations for inland monitors (right).** Note that map scales are variable and the maps for the inland county monitors show a much larger area than do those for monitors in lakeshore counties. (See notes in Figure 5.1 caption.)

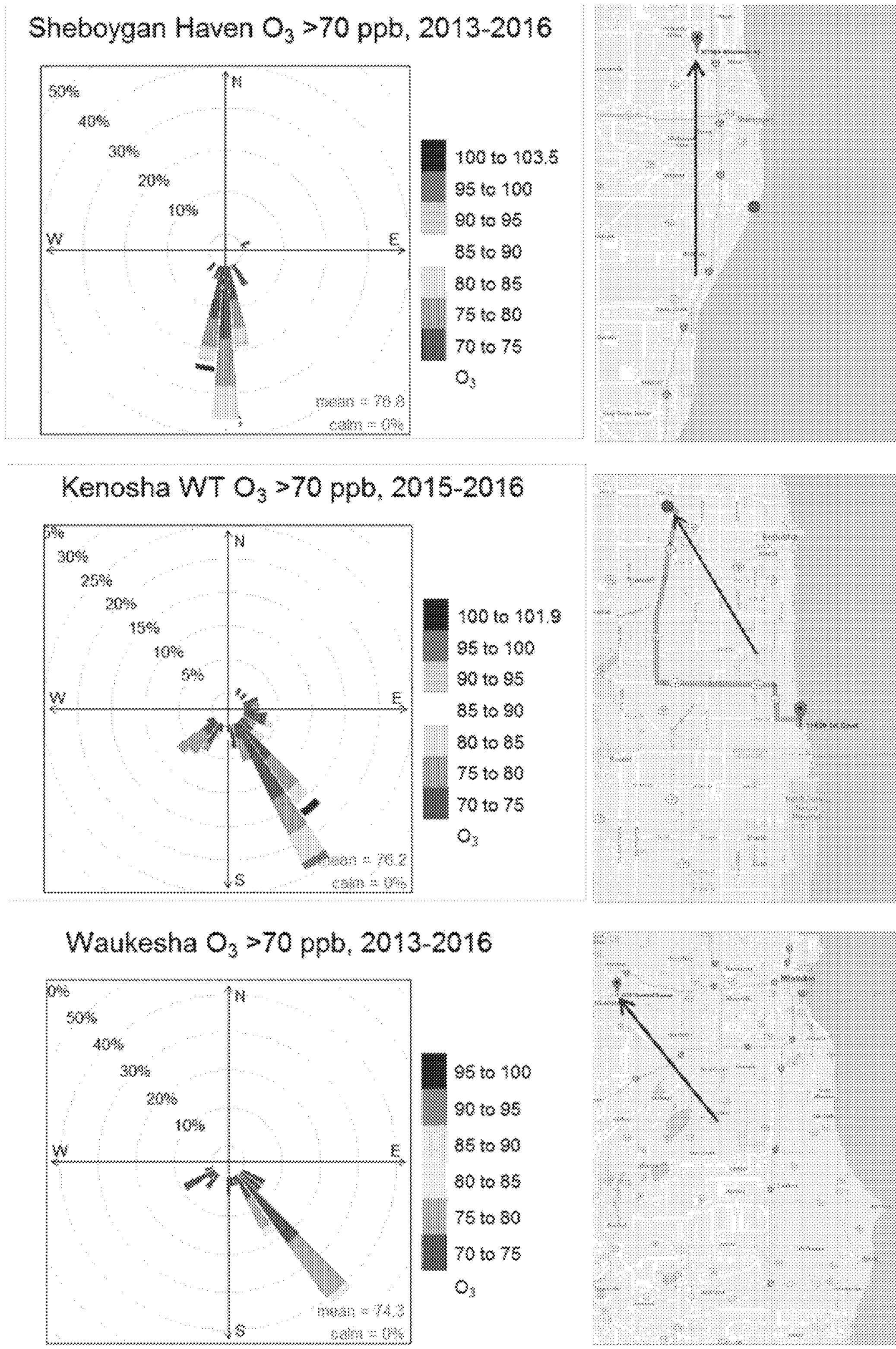
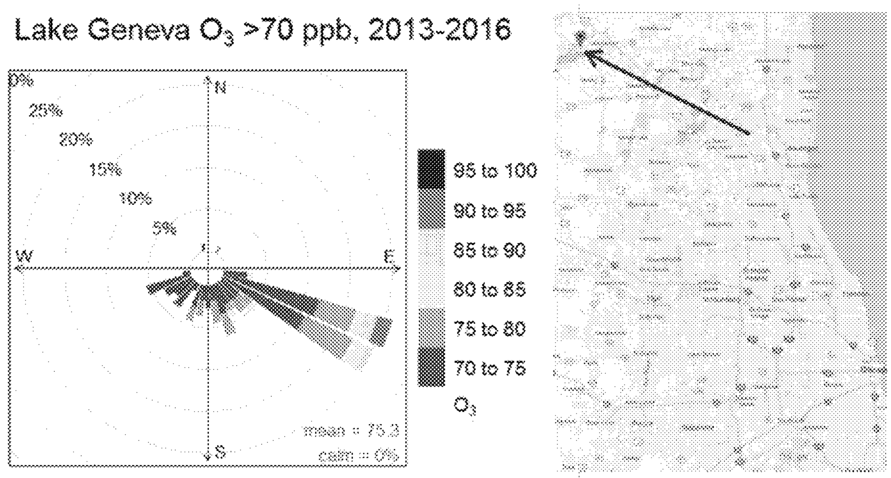


Figure 5.2. (continued)

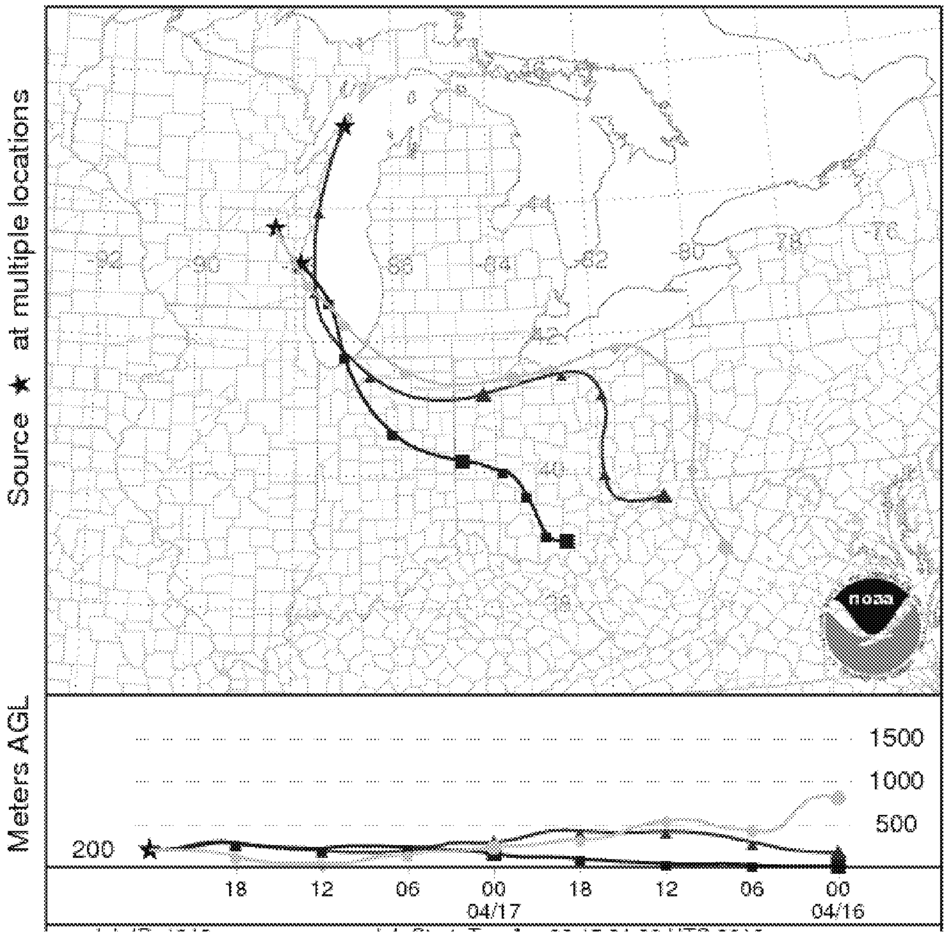


5.1.2. HYSPLIT Modeling Results

Back trajectories constructed using the HYSPLIT model help identify the source regions likely contributing to high ozone concentrations in Wisconsin. The HYSPLIT model uses meteorology for each day to outline the path an air parcel took to reach a given location, thus providing insight into the possible sources of ozone at that location.

As an example, Figure 5.3 shows back trajectories for a high ozone event on April 17, 2016 for three monitors, two on the lakeshore and one inland. These trajectories show the paths that air parcels took in the 48 hours prior to reaching their destination. These back trajectories show that the air reaching all three monitors travelled over Lake Michigan (and likely acquired some of its high ozone concentrations over the lake). Before reaching the lake, the air parcels traveled over northern Indiana and passed over parts of the Ohio River Valley, where they may have picked up additional ozone precursors.

Figure 5.3. HYSPLIT back trajectory analysis for monitors at Newport (red), Bayside (blue) and the inland Fond du Lac (green) monitors for 7 pm CDT on April 17, 2016. The bottom graph shows the elevation of each trajectory.



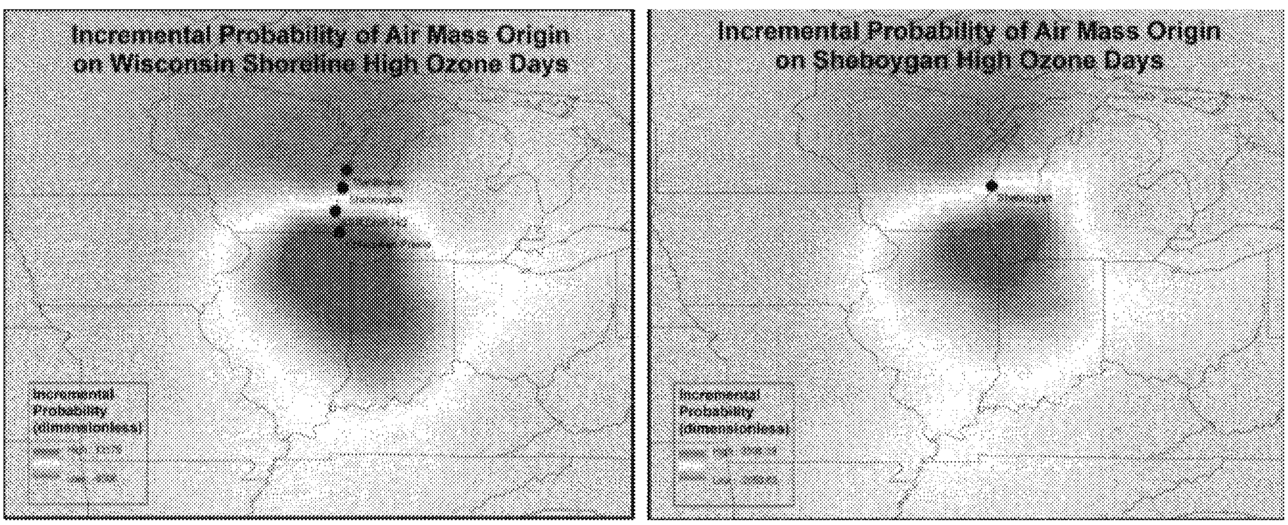
LADCO used the HYSPLIT model to construct back trajectories for each day during the years 2012 to 2015 at four different Wisconsin shoreline monitoring sites – Manitowoc, Sheboygan Kohler Andrae, Milwaukee SER ("SER DNR HQ") and Chiwaukee Prairie.[22] The LADCO HYSPLIT modeling results are shown in Figure 5.4 for all four shoreline monitors combined (left) as well as Sheboygan only (right). These results clearly indicate that, on high ozone days, ozone-rich air parcels are most likely to travel through northeast Illinois and northwest Indiana in the hours prior to reaching the Wisconsin monitoring sites. This is true for both analyses and strongly suggests that emissions from the greater Chicago area contribute significantly to ozone concentrations at these monitors. The results also show a high probability that, for the

[22] A full description of the methodology used can be found in the Modeling Demonstration for the 2008 Ozone National Ambient Air Quality Standard for the Lake Michigan Region – Technical Support Document, available at http://www.ladco.org/reports/ozone/index.php.

southernmost Wisconsin monitors, emissions from southern Indiana and the Ohio River Valley may also meaningfully contribute to ozone concentrations.

LADCO did not examine back trajectories for the ozone-rich air reaching Wisconsin's Newport monitor, located at the northeastern tip of Door County. This monitor is distant from the other monitors studied and is located northward of the monitor in Kewaunee County (which has a 2014-2016 design value below the 2015 ozone NAAQS).

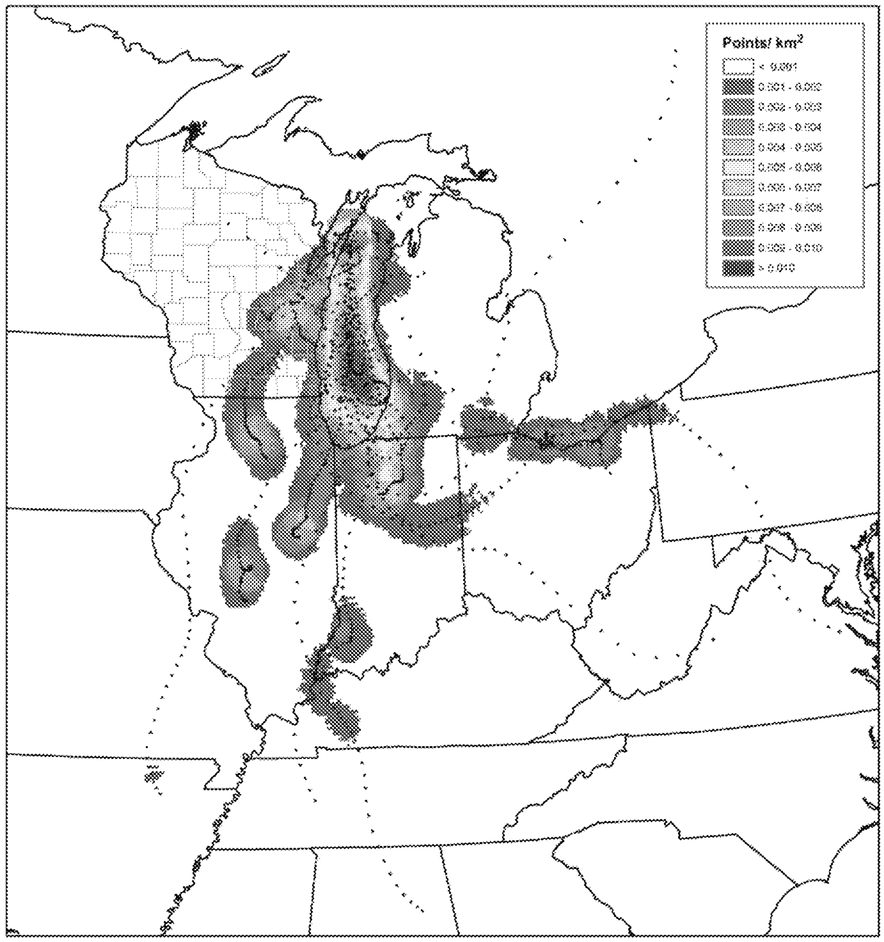
Figure 5.4. Incremental probability of air mass location in 72 hours prior to high ozone concentrations at Wisconsin shoreline monitors.



WDNR examined back trajectories for high-ozone days at the Newport monitor to determine whether the ozone-rich air reaching the monitor originated in the same manner as the ozone-rich air reaching lakeshore monitors to the south. Figure 5.5 shows that most of the trajectories traveled north up Lake Michigan to reach the remote Newport monitor. As is the case with the other Wisconsin lakeshore monitors, many of the trajectories traveled over the greater Chicago area, particularly over northern Indiana and southwestern Michigan. Other trajectories reaching the Newport monitor stretched farther west and/or farther south. Overall, the origins of ozone-rich air at the Newport monitor appear to originate from the south and from over the lake, which is consistent with results for other lakeshore monitors.

In summary, back trajectory analysis of HYSPLIT modeling confirms the crucial role played by transport of ozone and ozone precursors from source regions south of Wisconsin's lakeshore monitors. The next section examines the quantitative impacts of such transport.

Figure 5.5. 72-hour back trajectories for days with maximum daily 8-hour average ozone concentrations above 70 ppb during 2013-2016 at the Newport monitor. Points show hourly endpoints and the colors show the density of points in each area.



5.1.3. Source Apportionment Modeling Results

Source apportionment modeling quantifies the contributions of ozone from different regions and different source categories. The modeling is used here to examine the scale of interstate transport to the lakeshore monitors and the origins of that ozone.

Recent source apportionment modeling conducted by LADCO found that out-of-state emissions were responsible for 85 to 93 percent of the measured ozone concentrations at the lakeshore monitors (Figure 5.6). In addition, this modeling shows:

- The entire state of Wisconsin never contributed more than 15 percent of the ozone at any monitor and often contributed only 7 to 8 percent.
- At every monitor, Illinois contributed the greatest fraction of ozone, with the next greatest contribution coming from Indiana, Wisconsin or the “central” states (a region stretching from Texas and Louisiana north to Minnesota).

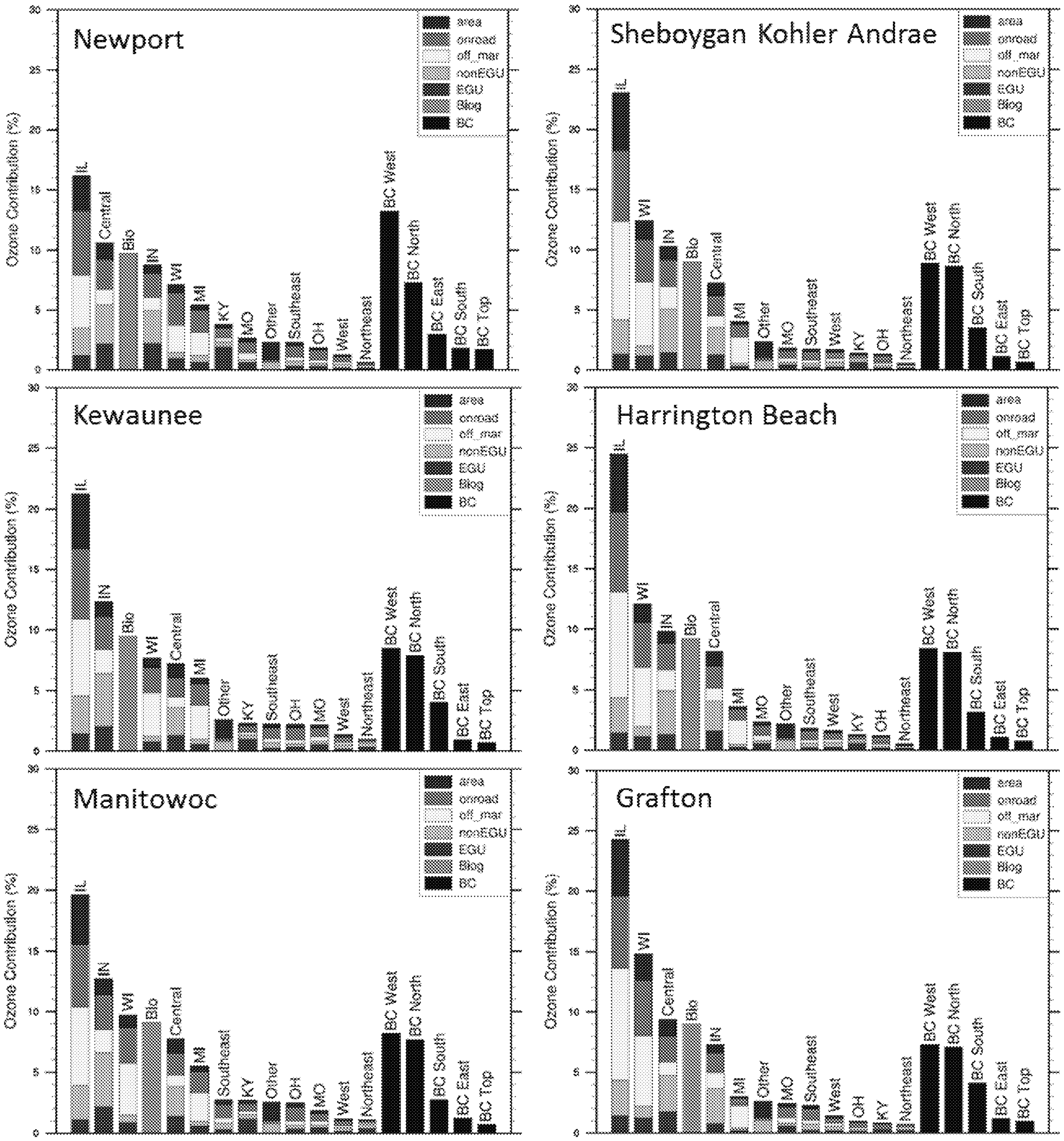
- Illinois's contribution was greatest near the Wisconsin-Illinois border and decreased to the north, contributing 16 percent at Door County's Newport monitor. Indiana's contribution followed an opposite pattern, with lower contributions to the southern sites and higher relative contributions to Kewaunee and Manitowoc in the north. This trend likely has to do with the wind direction required to deliver emissions from Indiana to Wisconsin's shoreline.
- Contributions from outside the U.S. ("boundary conditions") and from natural sources ("biogenics") contributed roughly a third of the ozone at Wisconsin's monitors.

The dominance of Illinois emissions to ozone measured at Wisconsin's lakeshore monitors is primarily due to two factors:

- Emissions from northeastern Illinois are much larger than those from all of Wisconsin's Lake Michigan lakeshore. Appendix A shows that both NO_X and VOC emissions from the nine counties in Illinois's portion of the Chicago area are more than three times larger than those from the ten counties that comprise Wisconsin's entire lakeshore region (including the Milwaukee metro area).
- Meteorology on high-ozone days carries these large amounts of emitted ozone precursors northward to Wisconsin, as was discussed in Chapter 3.

The source apportionment modeling result for the Newport monitor at the tip of Door County stands out in a number of different ways. Most notably, it had the lowest contribution from Illinois, receiving only 16 percent of its ozone from Illinois sources. The contribution from Wisconsin was also the lowest of any lakeshore monitor at around 7 percent. In contrast, this monitor received relatively large contributions from the central states, Kentucky and other distant states to the south, south-southeast and south-southwest. Finally, the Newport monitor received the largest contribution of any monitor from non-U.S. contributions, primarily from the western boundary. This unusual distribution underscores the distinctness of ozone transport to the Newport monitor.

Figure 5.6. Ozone source apportionment modeling from LADCO for Wisconsin's lakeshore monitors.[23] Colors correspond to emission source categories. Monitors are arranged from north to south within each column.



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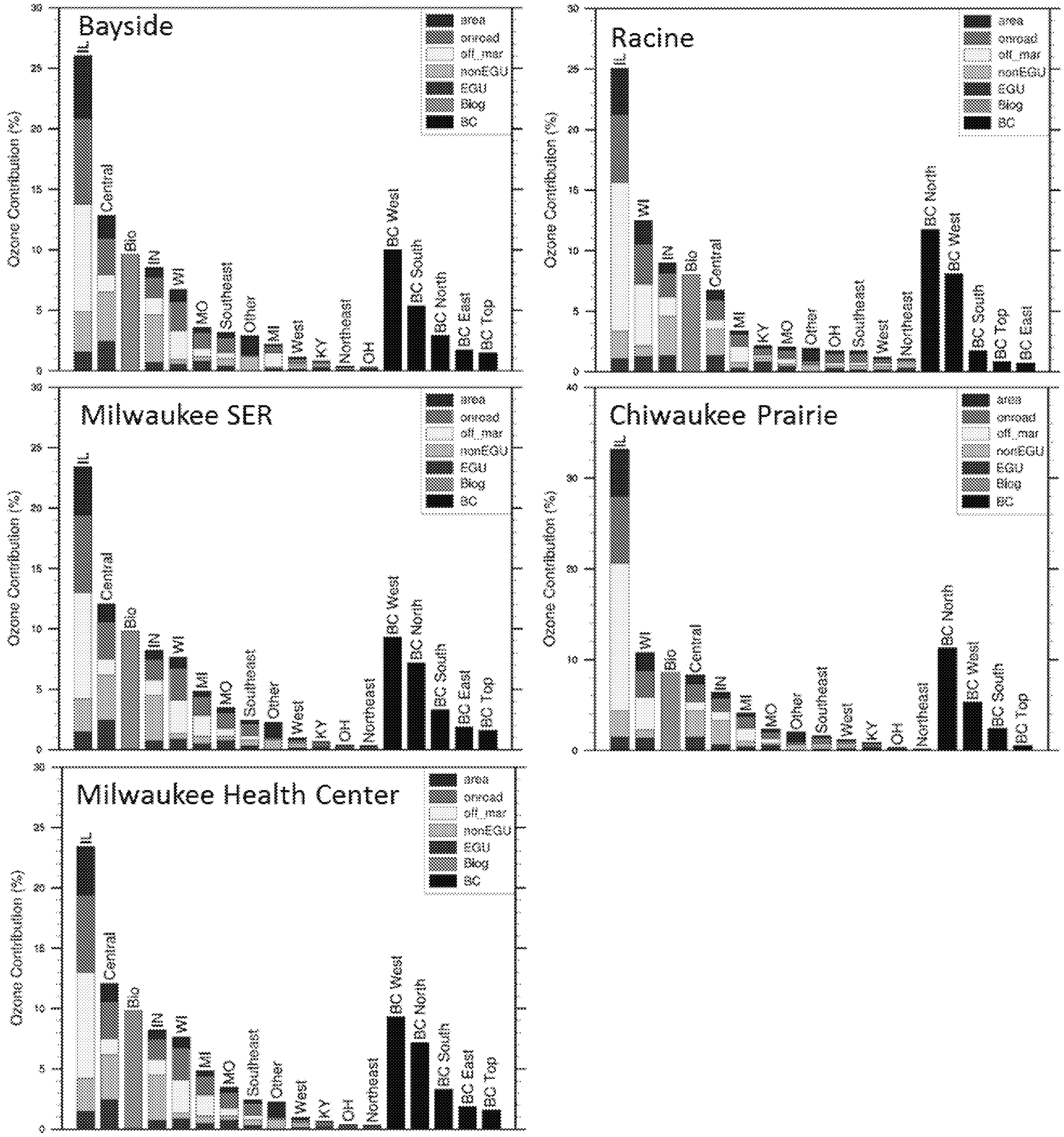
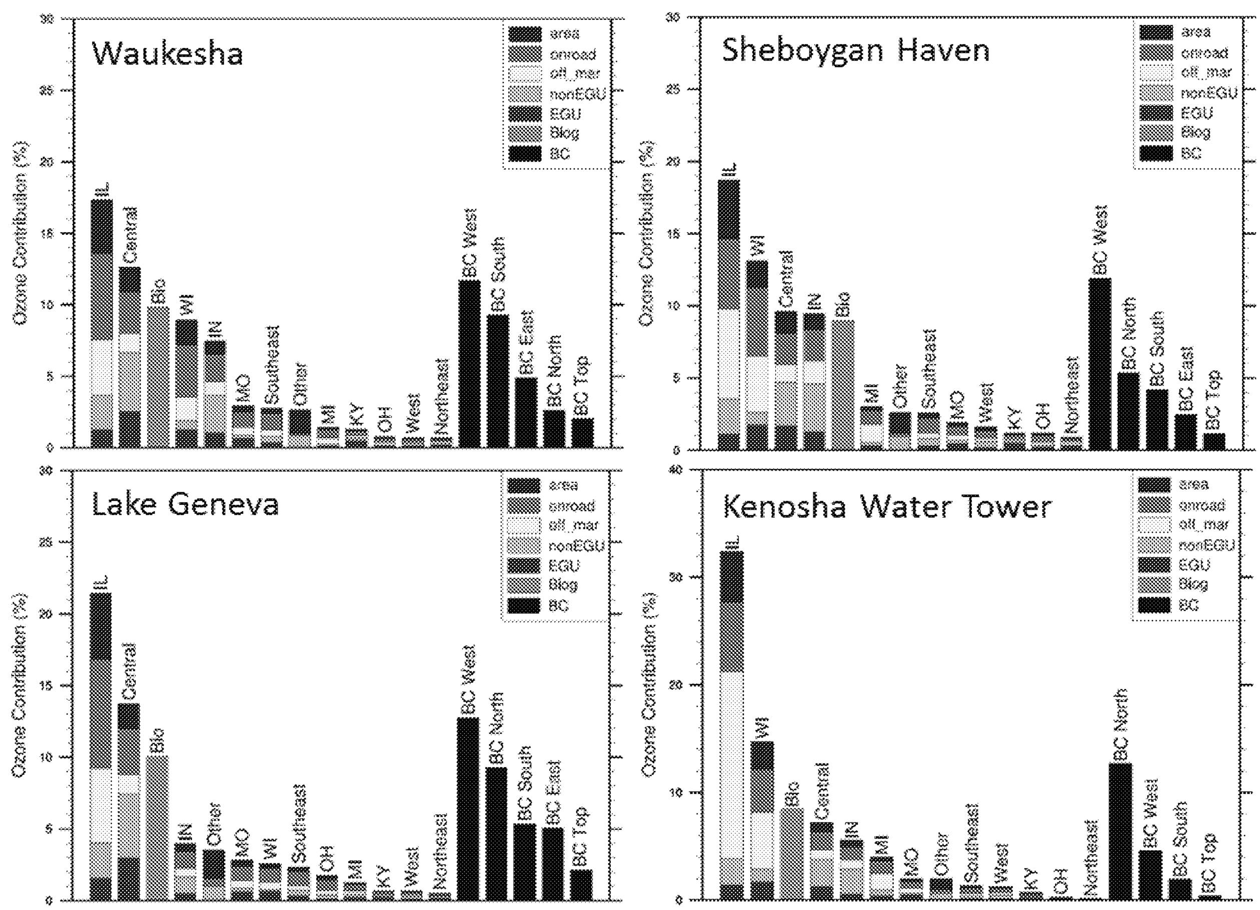
[23] The Central region includes MN, IA, NE, KS, OK, TX, AR and LA. The Southeast region includes MS, AL, GA, FL, TN, VA, NC and SC. The West region includes WA, OR, CA, NV, ID, MT, WY, UT, CO, AZ, NM, ND and SD. The Northeast region includes ME, NH, VT, MA, RI, CT, NY, NJ, PA, DE, MD, and WV. BC is boundary conditions, which are contributions from outside the U.S. "Bio" and "Biog" are biogenics.

Figure 5.6 (continued).



Ozone contributions at the inland monitors differed from those at nearby lakeshore monitors to varying degrees (Figure 5.7). While the distributions at the Kenosha Water Tower monitor were fairly similar to those at the nearby Chiwaukee Prairie monitor, the other three inland monitors (Sheboygan Haven, Waukesha, and Lake Geneva) varied more dramatically from their nearby lakeshore monitors.[24] All three of these inland monitors also received smaller contributions from states to the south than did the lakeshore monitors. These differences highlight the important role of the lake in transporting emissions from the south to the lakeshore and the smaller contribution of these sources to inland ozone concentrations.

Figure 5.7. Ozone source apportionment modeling from LADCO for Wisconsin's inland monitors.[23] Colors correspond to emission source categories. Monitors on the left are located in inland counties and on the right are located in lakeshore counties. Monitors are arranged from north to south within each column.



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[24] The Waukesha monitor was compared with the Milwaukee SER and Milwaukee Health Center monitors, the Lake Geneva monitor to the Chiwaukee Prairie monitor, and the Sheboygan Haven monitor to the Sheboygan Kohler Andrae monitor.

In addition, the two monitors in the inland counties (Waukesha and Lake Geneva) also received much larger percent contributions from boundary conditions (sources outside the U.S.) compared with the nearest lakeshore monitors. Overall, the same four source regions (Illinois, Indiana, Wisconsin, and central states) were the most important at all inland and lakeshore sites.[25]

In summary, source apportionment modeling shows that Wisconsin's Lake Michigan monitors are overwhelmingly impacted by ozone transported from out-of-state sources of emissions. This modeling also supports previous analyses suggesting that lakeshore and inland areas receive ozone from a different mix of source regions, underlining the distinctions between ozone concentrations measured at inland and lakeshore locations.

5.2. The Impact of Hypothetical Additional Emissions Reductions in Wisconsin

Analyses indicate that Wisconsin sources contribute little to ozone concentrations measured along the state's Lake Michigan shoreline. To assess what impact further emissions reductions from Wisconsin sources could potentially have on ozone concentrations in this transport-dominated region, LADCO conducted refined photochemical modeling for WDNR. This modeling examined the impact of two hypothetical emission reduction scenarios on the 13 monitors located in a 10-county area along Wisconsin's lakeshore:[26]

- Scenario 1: A 10 percent reduction in NO_X emissions and a 10 percent reduction in VOC emissions from all sectors (except from onroad and biogenics) from the 10-county area.[27]
- Scenario 2: Completely eliminating ("zeroing out") all anthropogenic NOx and VOC emissions from Sheboygan County. This scenario eliminated emissions from all sectors except for biogenic emissions, which were held constant.

Neither Scenario 1 nor Scenario 2 is feasible. These "what if" modeling scenarios were conducted with the objective of determining whether Wisconsin's lakeshore counties, on their own, have any ability to further reduce ozone design values at lakeshore monitors. These modeling runs help further examine the role of transported emissions in driving ozone in this area by determining whether transported ozone effectively overwhelms the impact of any potential additional reductions in local emissions.

[25] The exception is Lake Geneva, where Wisconsin's contribution ranked sixth among regions.
[26] The ten counties are Kenosha, Racine, Milwaukee, Waukesha, Ozaukee, Washington, Sheboygan, Manitowoc, Kewaunee, and Door.
[27] Reductions in onroad and biogenics sector emissions were not made since Wisconsin (like most other states) lacks any meaningful way to control emissions from these sectors. These reductions were made in the same ten counties as described in the previous footnote.

5.2.1. Overview

The projected design values for 2017 for the lakeshore and nearby inland monitors were compared with those determined from a recent base case modeling scenario.[28] Design values were calculated based on projections for all grid cells bordering the cell containing the monitor (a "3x3" grid cell area) and also considering projections for just the grid cell containing the monitor (a "1x1" grid cell area).[29] The results of these modeling runs are shown in Table 5.1.

Table 5.1. Model projected 2017 design values (DVs, in ppb) and changes in design values (ppb) for the 2017 base case modeling run and for two hypothetical emission reduction scenarios (described in the text). Design values are calculated considering modeled concentrations in either a 3x3 grid cell area or just the grid cell containing the monitor (1x1). Modeling was conducted by LADCO.

	Base Case DVs		10% Cut Run*				Zero-Out Sheboygan Run*			
			3x3 DVs		1x1 DVs		3x3 DVs		1x1 DVs	
Monitor	**3x3**	**1x1**	**DV**	**change**	**DV**	**change**	**DV**	**change**	**DV**	**change**
Chiwaukee Prairie	66.4	69.5	66.4	0	69.6	+0.1	66.3	-0.1	69.5	0
Racine	64.9	68.4	64.8	-0.1	68.5	+0.1	64.8	-0.1	68.4	0
Milwaukee Health Ctr	61	65.6	60.9	-0.1	65.6	0	60.9	-0.1	65.5	-0.1
Milwaukee SER	65.7	71.9	65.6	-0.1	72.2	+0.3	65.6	-0.1	71.7	-0.2
Bayside	70.9	75.5	70.8	-0.1	75.7	+0.2	70.7	-0.2	75.5	0
Grafton	69.7	71.4	69.7	0	71.4	0	69.7	0	71.4	0
Harrington Beach	66.8	68	66.7	-0.1	67.9	-0.1	66.8	0	67.9	-0.1
Kohler Andrae	76.1	77	76	-0.1	76.9	-0.1	76.1	0	77.6	+0.6
Manitowoc	70.9	71.6	70.8	-0.1	71.4	-0.2	70.8	-0.1	71.5	-0.1
Kewaunee	68.1	68.4	68	-0.1	68.3	-0.1	68	-0.1	68.1	-0.3
Newport	68.3	68	68.2	-0.1	67.9	-0.1	68.1	-0.2	67.8	-0.2
Lake Geneva	63.7	63.4	63.6	-0.1	63.3	-0.1	63.6	-0.1	63.3	-0.1
Waukesha	61.8	63	61.8	0	63.1	+0.1	61.8	0	63	0

*The "10% cut run" reduced VOC and NOx emissions by 10% from all sectors except onroad and biogenics in the 8 lakeshore counties along with Waukesha and Washington Counties. The "zero-out Sheboygan run" completely eliminated emissions from all sectors in Sheboygan County except for biogenics.

[28] The base case scenario can be found in the Modeling Demonstration for the 2008 Ozone National Ambient Air Quality Standard for the Lake Michigan Region – Technical Support Document, available at http://www.ladco.org/reports/ozone/index.php.

[29] The 3x3 grid cell approach is used by EPA for its modeled attainment tests and is their suggested default for state/regional modeling applications. Each grid cell is 12 kilometers by 12 kilometers. In this approach, the highest projected value from a 3x3 set of grid cells (9 grid cells total) is used to represent the 2011 base year and projected 2017 concentrations. A relative reduction factor is determined based on both these values and applied to a weighted 5-year design value centered on 2011 and based on monitored values at each site.

As shown in the table, under both scenarios most monitors show little to no change in their modeled 2017 design value (0.1 ppb or less) using either grid cell approach. The results of these two emission reduction scenarios are discussed in more detail below.

5.2.2. Scenario 1 Results

Projected design values showed almost no change in response to the 10 percent emissions cut across the 10-county area. Large, additional emissions reductions from the lakeshore area, which includes Wisconsin's most populous areas (including greater Milwaukee), would therefore have no meaningful impact on ozone design values at any of Wisconsin's lakeshore monitors. Design values are even projected to increase under this scenario at some monitors in the southern part of the lakeshore under the 1x1 grid cell approach, likely due to decreased titration effects in the urban center.

5.2.3. Scenario 2 Results

The results from the model run that eliminated all anthropogenic emissions from Sheboygan County were even more striking. Specifically, under the 3x3 grid cell approach, the design value at the Kohler Andrae monitor showed no decrease at all. Under the 1x1 approach, the design value at this monitor was actually predicted to *increase* by 0.6 ppb. Sheboygan County, therefore, has no ability to reduce ozone concentrations at the Kohler Andrae monitor. Some reductions in design values at monitors located north of the county were predicted under this scenario, but even these impacts were extremely small (generally, around 0.1 ppb).

5.2.4. Summary

LADCO modeling results clearly show that further reductions in nearby source emissions would have little, if any, impact on the monitored ozone concentrations in Wisconsin's lakeshore counties. Local emissions are essentially decoupled from the ozone concentrations registered in these counties. These results are also entirely consistent with what is understood about ozone transport and formation in this region as described earlier in this document.

This new information has significant impacts on the designations process. Specifically, these results show that designating nonattainment areas in the vicinity of any violating monitors would not offer any meaningful improvement on air quality; in fact, this may actually result in increasing ozone levels. These results also show that designating large nonattainment areas around lakeshore monitors, with the ostensible purpose of capturing the NOx and VOC emissions contributing to a violating monitor, simply is not supported when it comes to Wisconsin's lakeshore. Accordingly, given the limited influence of local emissions on lakeshore ozone concentrations, control of these nearby emissions should not be a factor considered by EPA when considering potential area designations in the state.

5.3. Conclusions

This chapter demonstrates that emissions contributing to high ozone concentrations along Wisconsin's Lake Michigan lakeshore are dominated by emissions transported from outside the state. In particular, these analyses strongly conclude that:

- Transport of ozone-rich air over Lake Michigan from the south is the dominant source of ozone at all lakeshore monitors in Wisconsin.
- Inland and lakeshore monitors in Wisconsin's southeastern counties (Kenosha and Walworth) receive some ozone transported over land from the Chicago area in addition to ozone transported over the lake.
- Transported ozone is responsible for elevated ozone concentrations observed at Wisconsin's lakeshore monitors.
- Further reductions in emissions from Wisconsin lakeshore counties, including the Milwaukee area, would have little to no impact on ozone design values at these monitors.

In summary, this analysis conclusively demonstrates that ozone monitors in Wisconsin's lakeshore area are overwhelmingly affected by transport from upwind areas and that the transport of large amounts of out-of-state emissions to the Wisconsin lakeshore effectively overwhelms any impact of local emissions on monitored ozone concentrations. As a result, Wisconsin has no ability to address its lakeshore ozone issues on its own. These results indicate that there are no air quality benefits to be gained by further controlling Wisconsin emissions for the purposes of the 2015 ozone NAAQS.

6. Implications for Area Designations for the 2015 Ozone NAAQS

6.1. The Need for a Flexible Designations Approach Given Wisconsin's Unique Circumstances

In this technical support document, WDNR demonstrates the unique situation of Wisconsin's lakeshore ozone monitors. These monitors are overwhelmingly affected by transport (Figure 5.6). Modeled reductions in ozone precursor emissions from Wisconsin's lakeshore counties had almost no impact on projected ozone design values within these counties (Table 5.1). This modeling confirms that the large amount of emissions transported to Wisconsin's lakeshore effectively overwhelms the impacts of local emissions within these counties. EPA itself stated its December 19, 2016 reclassification notice that Sheboygan's Kohler Andrae monitor "was not placed to monitor the maximum downwind impacts from the urbanized portion of the Sheboygan area, but to capture maximum downwind impacts from several urban areas along Lake Michigan, including Milwaukee, Wisconsin; Chicago, Illinois; and Gary, Indiana" (81 FR 91842).

The geography and meteorology of Wisconsin's Lake Michigan shoreline combine to maximize the amount of ozone delivered to its monitors. Such contributing factors include the location of major out-of-state emissions sources to the south, the presence of Lake Michigan to the east (which facilitates concentration and reaction of ozone precursors), and the frequent occurrences of lake breezes that pull the ozone onshore. This situation is of sufficient scientific interest that it is the target of a major research campaign during the 2017 ozone season, the Lake Michigan Ozone Study 2017 (LMOS 2017). During LMOS 2017, researchers from EPA, the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), and a number of research universities will conduct an extensive field study along the Lake Michigan shoreline. The goal of this study is to better understand the underlying physical and chemical mechanisms affecting ozone formation and transport along Wisconsin's lakeshore.

As demonstrated repeatedly in this document, ozone design values exceeding the level of the 2015 ozone NAAQS are confined to a narrow strip of land near the lakeshore. This means that the majority of the area of the lakeshore counties is not regularly affected by high enough ozone concentrations to justify a nonattainment status. Because of these unique circumstances and the overwhelming role of transport in driving ozone concentrations in this region, EPA should exercise the flexibility available to it to take a different approach than it has traditionally taken to designate areas for Wisconsin's lakeshore counties.

6.2. Support for the Governor's Recommendation for Attainment for all Wisconsin Counties

On September 21, 2016, Governor Walker recommended that EPA designate all counties in Wisconsin as attainment for the 2015 ozone NAAQS. This document provides extensive, data-driven support for the governor's recommendation.

This analysis demonstrates that any design values measuring above the level of the 2015 ozone NAAQS are confined to a narrow band that follows the lakeshore and are the result of out-of-state emissions. Modeling of additional hypothetical emissions reductions further indicates that Wisconsin has little to no ability to influence ozone concentrations at these monitors. Wisconsin counties should therefore not be designated nonattainment because of precursor emissions and resultant ozone that originates from beyond the state and over which Wisconsin has no control.

6.3. Maximum Extent of the 70 ppb Design Value Contour

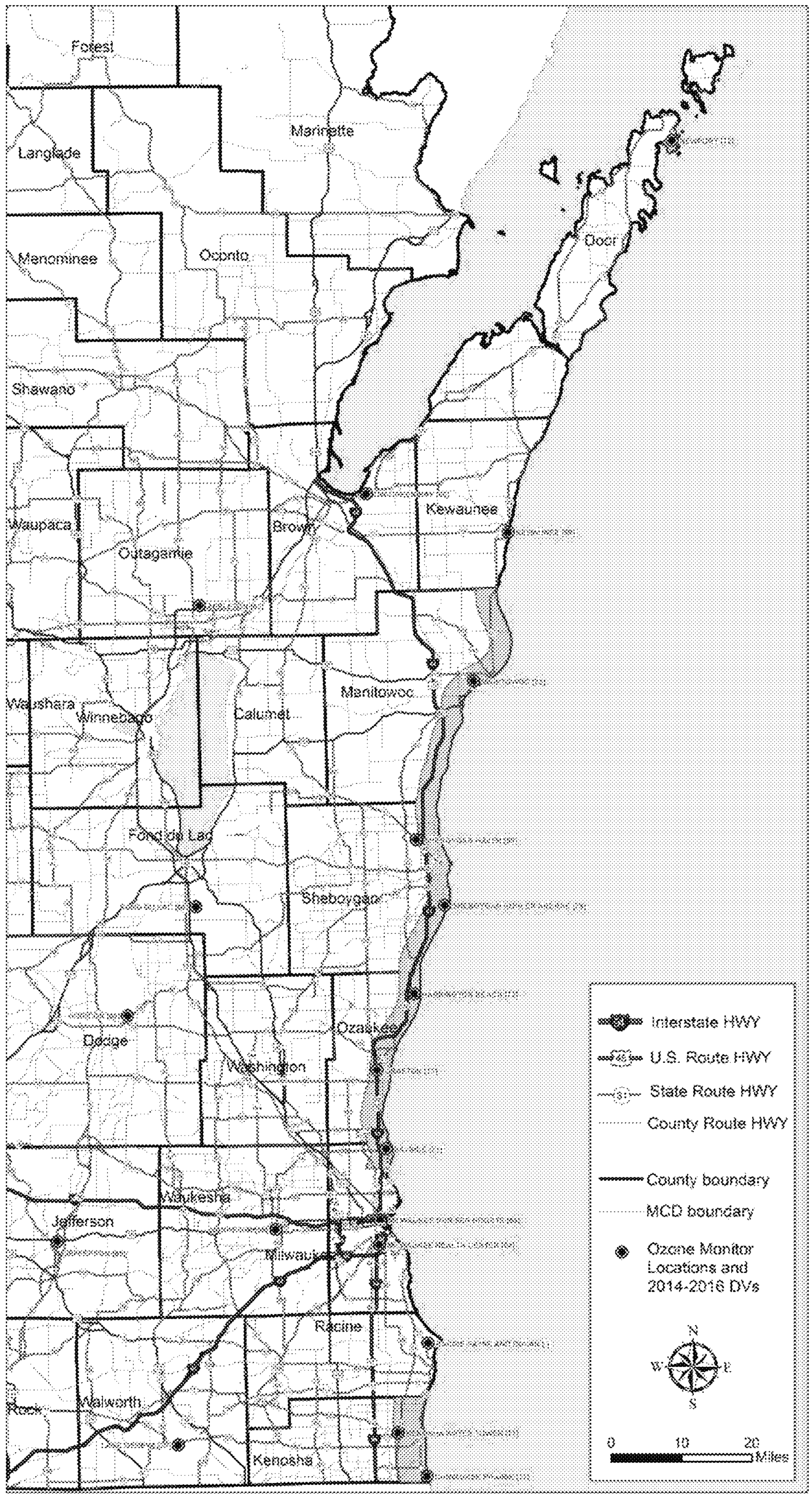
If EPA disregards the governor's recommendation and elects to impose nonattainment area designations on Wisconsin counties, the scientific data and analysis presented in this document shows that such areas must not extend beyond the narrow strip of land near the lakeshore that is impacted by high ozone design values. This chapter provides additional technical analysis that defines the location of the 70 ppb design value contour along Wisconsin's Lake Michigan shoreline. This 70 ppb contour represents the maximum extent of the area EPA could consider in the state should it finalize any nonattainment areas.

The location of this contour is shown graphically in Figure 6.1 and is further explained in the remainder of this chapter. Appendix D contains a larger version of Figure 6.1.

6.3.1. Calculating the 70 ppb Ozone Design Value Contour

An ozone design value would attain the 2015 ozone NAAQS at a value of 70 ppb or lower. To determine the spatial extent of the area along the lakeshore that may exceed this value, it is crucial to estimate the location of the "contour" of air with a design value of 70 ppb. This section discusses two approaches to identifying the contour. The first examines the trends in ozone design values at monitors relative to distance inland from the lakeshore. The second examines the gradients in the two counties (Sheboygan and Kenosha) with both inland and lakeshore monitors.

Figure 6.1. Map of the 70 ppb design value contour along Wisconsin's Lake Michigan shoreline. The 70 ppb design value contour as described in Chapter 6 is shaded. Appendix D contains a larger version of this figure.



Ozone design values relative to distance from the lakeshore

Evaluation of how ozone design values at the lakeshore monitors change with distance from the shoreline suggests that the 70 ppb contour lies just a few miles inland from Lake Michigan. Table 6.1 lists the inland distance for each monitor, and Figure 6.2 plots the design values versus these distances. The figure shows that most of the monitored design values fall very close to a line with a power fit (rather than a linear fit). This suggests that ozone design values drop off very sharply within the first half mile of the shoreline and then decrease more gradually with distance. The finding that the inland Waukesha monitor, located 16 miles inland from Lake Michigan, falls neatly along this line suggests that distance from the lakeshore is a primary driver of ozone concentrations even this far inland.[30] The best-fit line reaches 70 ppb at an inland distance of 2.3 miles, which suggests that the 70 ppb design value contour lies around 2.3 miles inland for much of the lakeshore.

Table 6.1. Distance inland and 2014-2016 design values for ozone monitors along Wisconsin's Lake Michigan lakeshore and nearby inland counties.

Monitor	Distance Inland (miles)	2014-2016 Design Value (ppb)
Chiwaukee	0.15	77
Kenosha Water Tower	3.6	71
Racine Payne & Dolan	1.2	--
Milwaukee Health Ctr	2	64
Milwaukee SER	1.5	68
Bayside	0.8	71
Grafton	1.9	71
Harrington Beach	0.8	73
Kohler Andrae	0	79
Sheboygan Haven	3.2	69
Manitowoc	0.8	72
Kewaunee	0.14	69
Newport	0.4	72
Lake Geneva	35	70
Waukesha	16	66

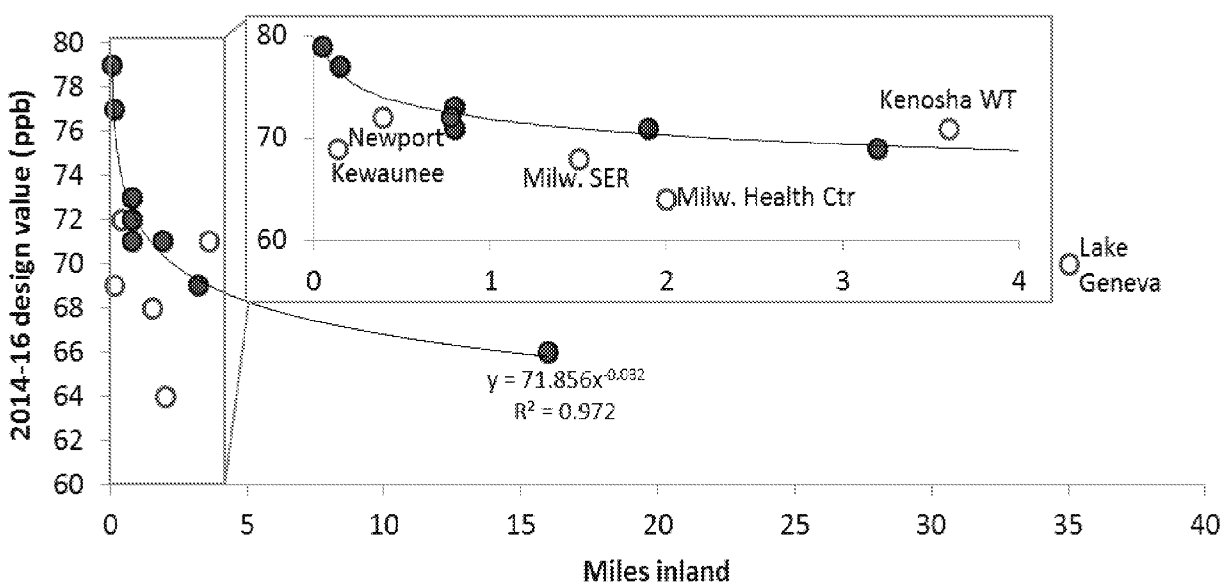
[30] Note that the equation calculated for the best fit line is almost identical without the Waukesha monitor, so the values for this monitor are not driving the equation for the line.

The finding that most of the monitors' design values fall on the same best-fit line suggests that a consistent relationship exists between design values and distance inland along most of the lakeshore. This suggests that this 70 ppb design value contour likely applies to most of the Wisconsin lakeshore.

There are straightforward explanations for the observed variations at the monitors whose design values do not fall along this line, as described below.

The design values at the Kenosha Water Tower and Lake Geneva monitors fall above the best-fit line for most of the monitors. These inland monitors are known to receive significant ozone during events that directly transport ozone from the Chicago area over land to these locations, as discussed in Chapter 5. Such transport does not depend directly on the distance from the lakeshore because ozone formed over the lake is not the only source of ozone. Thus, distance from the lakeshore is not the only factor driving ozone concentrations for these monitors.[31] This finding suggests the 70 ppb contour may be located slightly farther inland in Kenosha County than in most of the rest of the lakeshore.

Figure 6.2. 2014-2016 design values plotted against the distance inland from Lake Michigan for all monitors in lakeshore counties and neighboring Waukesha and Walworth counties. The best-fit line was plotted using the monitors with filled symbols using a power fit. Monitors that were not included in the best fit line are labeled.



[31] While the Chiwaukee Prairie monitor also receives some ozone via direct transport events, its design value still falls on the best-fit line. This likely occurs because this monitor receives its peak ozone concentrations from transport over the lake, not over land, so that the inland distance from the lakeshore is the primary factor affecting its ozone design values.

The design values for the two central Milwaukee monitors are located well below the best-fit line for most of the monitors. This is likely due to urban effects on ozone formation.[32] The lower-than-expected ozone design values at these monitors suggest that ozone design values throughout this urban area likely do not exceed the 2015 ozone NAAQS at all. Note that the 2014-2016 design value at the Bayside monitor in the northeastern corner of Milwaukee County was above the 2015 ozone NAAQS and lies on the best-fit line. This monitor is located outside the core urban area and therefore likely is not subject to the same urban effects as the two other monitors in the county.

Finally, the 2014-2016 design values at the northern monitors at Kewaunee and Newport are below the best-fit line. This indicates that ozone concentrations at these monitors are lower than would be anticipated in counties to the south. This deviation suggests that other factors are driving ozone concentrations at these monitors, likely due to their greater distance from emission sources to the south and the greater transport time needed for ozone to reach these monitors. The greater transport time allows pollutants in the transported air more time to undergo additional reactions, which could alter the composition of the pollutants. These differences suggest that the 70 ppb design value contour cannot be defined in the same way in Door County as it is farther south.

Comparison of inland and lakeshore monitor data in Sheboygan County

As previously discussed, Sheboygan County has two ozone monitors that have been operating since at least 2014 – one inland monitor (Sheboygan Haven) and one lakeshore monitor (Kohler Andrae). As shown in Table 6.1, the 2014-2016 design value at the lakeshore monitor was 10 ppb higher than that at the inland monitor. The inland monitor is 3.2 miles farther inland than the lakeshore monitor. The analysis in Figure 6.2 suggests that design values decrease with increasing distance from the lakeshore following a power function. However, in comparing the inland and lakeshore monitors a more conservative assumption is made that design values decrease in a linear fashion moving inland from the lake.

A linear decrease yields a presumptive concentration gradient of $\frac{10\,ppb}{3.2\,miles}$. A design value of 70 ppb is 9 ppb lower than the design value at the Kohler Andrae monitor. Assuming a linear concentration gradient, we would expect 70 ppb design values to occur at a distance of:

$$9\text{ ppb} * \left(\frac{3.2\,miles}{10\,ppb}\right) = 2.9\text{ miles inland}$$

[32] High NOx concentrations in urban centers have been shown to reduce ozone concentrations due to titration and reductions in ozone formation rates. See, for example, EPA (2013) Integrated Science Assessment for Ozone and Related Photochemical Oxidants. http://ofmpub.epa.gov/eims/eimscomm.getfile?p_download_id=511347 .

This linear extrapolation for Sheboygan County yields a 70 ppb contour that is consistent with, but 0.6 miles farther inland than, the contour estimated using the best-fit line in the previous section (2.3 miles). This analysis suggests that the use of a linear interpolation to determine the 70 ppb contour allows for a margin of safety. As previously shown, there seems to be a consistent relationship between design values and distance inland for much of the lakeshore. A distance of 2.9 miles inland from the lakeshore is therefore a conservative calculation of the 70 ppb contour along much of Wisconsin's Lake Michigan lakeshore.

Comparison of inland and lakeshore monitor data in Kenosha County

Kenosha County also has two ozone monitors, one inland (Kenosha Water Tower) and one on the lakeshore (Chiwaukee Prairie) which have been operating since at least 2013 (Figure 4.2). As shown in Table 6.1, the 2014-2016 design value at the lakeshore monitor was 6 ppb higher than that at the inland monitor for the design value year. The inland monitor is 3.45 miles farther inland than the lakeshore monitor. Using the same method described above, this calculation conservatively assumes that concentrations decrease linearly between the lakeshore and inland monitors. This calculation yields a presumptive concentration gradient of $\frac{6\ ppb}{3.45\ miles}$. A design value of 70 ppb is 7 ppb lower than the design value at the Chiwaukee Prairie monitor. Assuming a linear concentration gradient, the 70 ppb design value contour would occur at a distance of:

$$7\text{ ppb} * \left(\frac{3.45\ miles}{6\ ppb}\right) = 4.0\text{ miles inland from the Chiwaukee Prairie monitor}$$
$$= 4.15\text{ miles inland from the lakeshore} \approx 4.2\text{ miles inland from the lakeshore}$$

A distance of 4.2 miles inland from the lakeshore is therefore a conservative calculation of the location of the 70 ppb design value contour in Kenosha County.

This calculation shows that the 70 ppb contour appears to be wider in Kenosha County than in Sheboygan County. This is consistent with the finding that the design value for the Kenosha Water Tower monitor is above the inland trend created by most of the lakeshore monitors (Figure 6.2), including those in Sheboygan County. These differences likely occur because of Kenosha's proximity to the Chicago area. This proximity allows winds to transport ozone-rich air over land from the Chicago area to inland parts of Kenosha County without transport over the lake. Evidence for such direct transport is presented in Chapter 5. Any such overland plumes are likely to be diluted significantly by turbulent mixing as they travel northward. Such mixing occurs at much greater rates over land than over the relatively cold and flat lake surface. Such direct transport of ozone-rich air from the Chicago area does not appear to play an important role at more distant northern monitors, as discussed for Racine County below.

6.3.2. Application of the 70 ppb Design Value Contour to Individual Counties

The following applies the 70 ppb contour methodology described above to Wisconsin's lakeshore counties and those counties in the greater Milwaukee area that may have 2014-2016 design values at or near the level of the 2015 ozone NAAQS. This section only describes how that scientifically-derived contour could be applied. Nothing in these descriptions should be construed as a recommendation for a potential nonattainment area designation for the 2015 ozone NAAQS. The counties are listed starting from the south.

Kenosha County

Based on the monitor data analysis described above, WDNR estimates that the 70 ppb design value contour is located no greater than 4.2 miles inland from the lakeshore in Kenosha County.

Racine County

WDNR ceased operating a long-running ozone monitor in Racine County at the end of 2013 due to safety concerns at the site. In 2015, WDNR began operating a new monitor in the county at the "Payne and Dolan" site. The lack of ozone monitoring data for 2014 makes it impossible to calculate a 2014-2016 design value (see Table 6.2).

Given the lack of 2014 data, it is impossible to predict with certainty whether this monitor would have attained or violated the NAAQS over the 2014-2016 period. EPA states in its designation guidance that monitors with incomplete data may be designated "unclassifiable." If EPA does not designate Racine County as attainment for the 2015 ozone NAAQS, EPA should consider an unclassifiable designation in this county.

Table 6.2. Fourth high maximum daily 8-hour average ozone concentrations for the Racine Payne and Dolan monitor during the 2014-2016 design value period.

Monitor	Fourth High Maximum Daily 8-Hour Average Concentrations (ppb)		
	2014	2015	2016
Racine Payne & Dolan	-	68	76

However, if this monitor was somehow found by EPA to measure values above the 2015 ozone NAAQS in spite of the missing year of data, the location of the 70 ppb design value contour would be closer to the lakeshore than that in neighboring Kenosha County. Almost no ozone-rich air was observed arriving at the old Racine monitor from the south-southwest or southwest (Figure 5.1).[33] This is in contrast to the significant contributions from these directions at the

[33] Wind direction is not measured at the Racine Payne and Dolan monitor, so the pollution rose shown for Racine uses data from 2010-2013 for the original Racine monitor.

Kenosha County monitors, as discussed previously. This suggests that Racine County is not subject to the same direct transport mechanism as is Kenosha County and thus does not receive elevated ozone concentrations inland from the lakeshore. It follows that the 70 ppb contour would be located closer to the lakeshore in Racine County than the 4.2-mile distance supported for Kenosha County.

Milwaukee County

Only one of the three monitors in Milwaukee County (the Bayside monitor) had a 2014-2016 design value above the level of the 2015 ozone NAAQS (Table 6.1). The Bayside monitor is located in the far northeastern corner of the county, significantly away from, and north of, the urban core. The design value for this monitor is part of the best-fit line comparing design values with distance inland from the lakeshore. This suggests that the 70 ppb design value contour in this area would be located at the same distance inland as in most other parts of the lakeshore. This distance is conservatively estimated at 2.9 miles inland based on comparison of the inland and lakeshore monitoring data in Sheboygan County.

The two monitors located in central Milwaukee County (Milwaukee SER and Milwaukee Health Center) have 2014-2016 design values that are below the 2015 ozone NAAQS (64 ppb and 68 ppb, respectfully) (Table 6.1). These lower design values likely result from urban effects on ozone formation (discussed in Section 6.3.1) and indicate that this portion of Milwaukee County is attaining the 2015 ozone NAAQS.

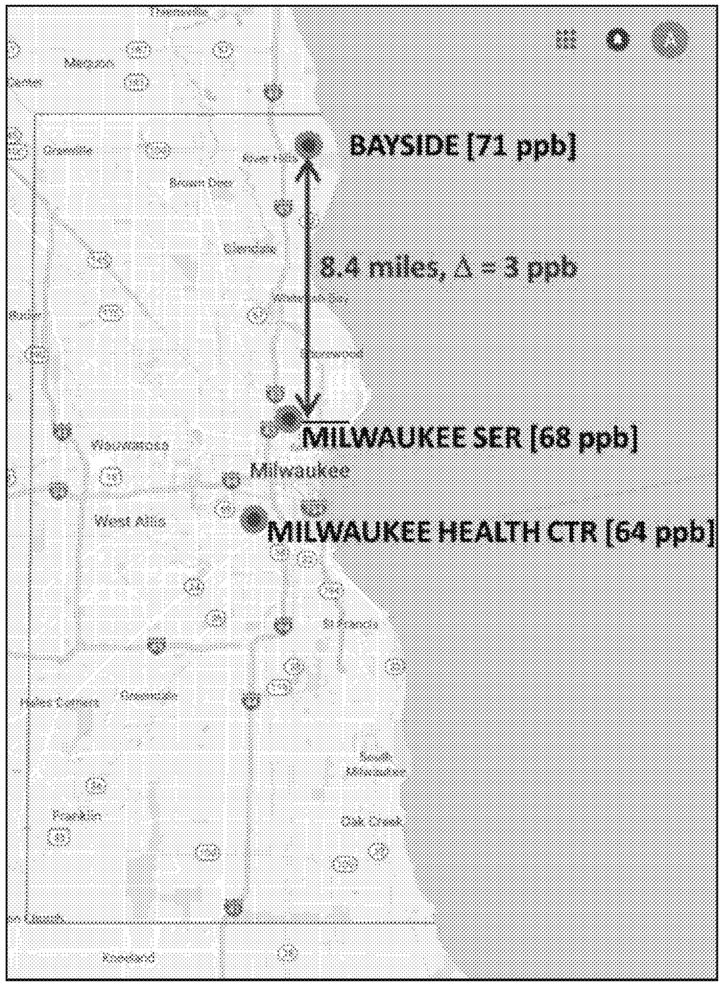
There is no additional information about the where the north/south boundary of the 70 ppb contour might be in Milwaukee County. In the absence of additional information, it is appropriate to assume that design values changed linearly in a north-south direction between the county's ozone monitors. The locations and design values for the relevant monitors are shown in Figure 6.3. Comparison of the Bayside monitor with the Milwaukee SER monitor suggests there is a concentration gradient of $\frac{3\ ppb}{8.4\ miles}$ in the northern part of the county. The design value would only need to be 1 ppb lower than that at the Bayside monitor. Assuming a linear concentration gradient, we would expect 70 ppb concentrations to occur at a distance of:

$$1\text{ ppb} * \left(\frac{8.4\ miles}{3\ ppb}\right) = 2.8\text{ miles south of the Bayside monitor}$$

Similarly, there is no monitoring data to inform whether the southern part of Milwaukee County may be experiencing design values that exceed the 2015 ozone NAAQS.

Taken together, the 70 ppb contour in Milwaukee County is estimated to be 2.9 miles from the lakeshore in the northeastern portion of the county. This contour would extend only 2.8 miles south of the Bayside monitor before cutting due east to the coastline, as shown in Figure 6.1.

Figure 6.3. Locations and 2014-2016 ozone design values for monitors in Milwaukee County, with the north-south and concentration differences shown in red. The county boundary is shown in blue.



Waukesha and Washington Counties

Waukesha and Washington Counties are part of the Milwaukee-Waukesha-West Allis Metropolitan Statistical Area. In the past, these counties have been designated as part of the Milwaukee area, together with Milwaukee, Racine, Ozaukee and sometimes Kenosha counties.

This document clearly demonstrates that design values exceeding the level of the 2015 ozone NAAQS are confined to a narrow area along the Lake Michigan lakeshore. The high ozone air (and the 70 ppb design value contour) does not reach far enough inland to affect either Waukesha or Washington Counties. In fact, the only ozone monitor in these two counties, the Waukesha monitor, has a certified 2014-2016 design value of 66 ppb, well below the level of the 2015 ozone NAAQS.

Ozaukee, Sheboygan, and Manitowoc Counties

The design values for the monitors in Ozaukee, Sheboygan, and Manitowoc Counties all fell along the best-fit line comparing design values with distance inland from the lakeshore (Figure 6.1). This suggests that the location of the 70 ppb design value contour line would fall the same distance from the lakeshore in these counties, determined to be 2.9 miles inland as described earlier based on the data from the Sheboygan County monitors.

Kewaunee County

The monitor in Kewaunee County had a 2014-2016 design value of 69 ppb, which is below the level of the 2015 ozone NAAQS. This monitor is located very close to the shoreline (0.14 miles), a location equivalent to the Chiwaukee Prairie site in terms of proximity to the shoreline. Accordingly, no part of Kewaunee County is estimated to be in the 70 ppb contour.

Door County

The 2014-2016 design value for Door County's only monitor, at Newport State Park, is 72 ppb. A number of factors demonstrate that Door County is in a unique situation relative to ozone formation and transport compared with the other lakeshore counties:

- The design value at the Newport monitor is below the trend for design values versus distance inland for most lakeshore monitors (Figure 6.2), as did the Kewaunee monitor to the south. This suggests differences in the factors influencing ozone concentrations in this area, likely due to the remoteness of this monitor relative to the major out-of-state emissions source regions to the south.
- Door County is located to the north of Kewaunee County, whose ozone monitor had a design value (69 ppb) below the 2015 ozone NAAQS for the 2014-2016 period. It is probable that the area with design values attaining the standard extends northward from Kewaunee County into Door County.
- This monitor is located at the far northeastern tip of the Door peninsula, which juts northeastward into Lake Michigan. The monitor itself is located on high ground in Newport State Park and is surrounded on nearly three sides by water. This exposed location is the most likely spot in Door County to intercept ozone-rich air transported from the major metropolitan areas to the south.
- Door County is located east of the ozone monitor located in Green Bay. Despite being in an area with significantly more sources of emissions, the Green Bay monitor had a 2014-2016 design value of 66 ppb, further suggesting the ozone concentrations in Door County are not the result of local emissions.
- Source apportionment modeling for this monitor shows that the distribution of source regions at this monitor differs from that found at counties located to the south (Figure 5.6).
- This county is extremely rural, with very few sources of emissions.

Ozone concentrations are therefore driven by different factors in Door County than in the other lakeshore counties. Given the lack of local emissions, the unusual geography, and the fact that the monitored ozone concentrations are the result of ozone transported from the south over the lake, there is no evidence that the 70 ppb contour extends beyond the boundary of Newport State Park.

As stated in EPA's guidance, section 182(h) of the CAA provides EPA with the discretion to designate an ozone nonattainment area as a rural transport area (RTA). In order for a nonattainment area to be classified as an RTA, the nonattainment area boundary may not include or be adjacent to any part of a Metropolitan Statistical Area (MSA). Should EPA designate a nonattainment area in Door County, any potential nonattainment area would therefore be eligible for classification as an RTA since Newport State Park does not include and is not adjacent to any part of an MSA.

EPA also requires that RTAs not contain VOC and NO_X emission sources that make a significant contribution to monitored ozone concentrations in the area or in other areas. As shown in Appendix A, all of Door County contributes only one percent of NOx and VOC emissions to the Lake Michigan region (excluding Michigan). There were only 11 point sources in Door County in 2014 that emitted a total of 8.6 tons of NOx and 79.8 tons of VOCs. In addition, there are no emission sources located within the boundaries of Newport State Park except for a very small amount of mobile source emissions. In contrast, the extensive analyses included in Chapter 5 demonstrate that emissions originating from outside of the state of Wisconsin contribute overwhelmingly to the elevated ozone levels measured at Door County's ozone monitor. Taken together, any potential ozone nonattainment area finalized by EPA in Door County, particularly one defined as the boundary of Newport State Park, would meet the second requirement to be eligible as a RTA.

6.4. Conclusions

This document supports the governor's recommendation that all areas of the state be designated attainment for the 2015 ozone NAAQS. If EPA does not follow this recommendation, this chapter has provided extensive, well-supported analysis to conclusively show that ozone design values above 70 ppb are limited to within 2.9 miles of Lake Michigan for most of the Wisconsin lakeshore and within 4.2 miles in areas impacted by direct overland transport. This finding is based on the latest available monitoring data and extensive analysis of the meteorological effects that transport high ozone air to the Wisconsin lakeshore. Any nonattainment areas EPA elects to impose must adhere to this science-based, "distance from the shoreline" approach, rather than on arbitrary boundaries based on historical practice or outdated theories of how local emissions impact ozone levels in the state.

This submittal provides compelling, data-driven evidence for what has long been understood: Wisconsin's ozone problems are due to transported pollutants, exacerbated by the unique effects of Lake Michigan, and are not meaningfully affected by in-state emissions. EPA's repeated unwillingness to fully address the impacts of ozone transport on Wisconsin has left the state to address its nonattainment issues on its own. Wisconsin has met this challenge by implementing many measures to reduce pollutants and operating one of the best-controlled utility fleets in the nation. However, the science is clear: there are no demonstrable benefits to be gained by further controlling emissions in the state for the purpose of this standard. EPA must acknowledge this information and use the discretion it has under the CAA to avoid imposing nonattainment areas on the state that would not improve air quality.

WDNR reserves the right to review the information contained in this document and supplement it at any time in order to provide EPA with the latest and most comprehensive information regarding the ozone concentrations in Wisconsin's lakeshore region.

APPENDIX A

Regional Emissions Data

This appendix provides information about ozone precursor emissions of nitrogen oxides (NOx) and volatile organic compounds (VOC) from sources located along Wisconsin's lakeshore and the neighboring Lake Michigan region.

Methodology and Source Categories

Wisconsin utilized 2014 National Emission Inventory (NEI) data to characterize regional NOx and VOC emissions for 23 counties in and around the Wisconsin lakeshore region. This area includes the eastern Wisconsin Lake Michigan shoreline counties, all of the Milwaukee-area counties, and the counties in the Chicago-Naperville-Elgin, IL-IN-WI Core-Based Statistical Area (Table A.1). NOx emissions data for electric generating units from the 2014 from EPA's Clean Air Markets Division database were also incorporated into the emissions inventory.

Table A.1 Chicago-Naperville-Elgin, IL-IN-WI Core-Based Statistical Area counties. (U.S. Census Bureau, February 2013)

Illinois Counties	Indiana Counties	Wisconsin Counties
Cook	Jasper	Kenosha
DeKalb	Lake	
DuPage	Newton	
Grundy	Porter	
Kane		
Kendall		
Lake		
McHenry		
Will		

The NEI is a comprehensive and detailed estimate of air emissions of criteria pollutants, precursors to criteria pollutants, and hazardous air pollutants. The NEI is released every three years based primarily upon data provided by state, local, and tribal air agencies for sources in their jurisdictions and supplemented by data developed by EPA. The NEI groups sources into different categories, including point, area, non-road mobile, and on-road mobile source categories.

Point sources include emissions from fixed stationary sources such as electric utilities, industrial, commercial and institutional facilities, airports, and smaller industrial, non-industrial and commercial facilities. A small number of portable sources such as some asphalt or rock crushing operations are also included. For Wisconsin, point sources include those emitting five or more tons of NOx in a year and/or three tons of VOC in a year. Illinois and Indiana point source emissions were taken directly from the NEI database.

Nonpoint sources include emissions estimates for stationary sources which individually are too small in magnitude to report as point sources. These emissions sources are included in the NEI as a county total or tribal total (for participating tribes). Examples include residential heating, commercial combustion, asphalt paving, and commercial and consumer solvent use. Emissions attributable to biogenic sources (e.g., soil and vegetation) were removed from the dataset so that only anthropogenic emissions are included in the inventory. The NEI also includes certain mobile sources, including marine vessels and railroad equipment, in the nonpoint source category. Those emission sources were moved into the *Nonroad* category for the purposes of this emissions inventory.

Onroad sources include emissions from onroad vehicles that use gasoline, diesel, and other fuels. These sources include light duty and heavy duty vehicle emissions from operation on roads, highway ramps, and during idling. EPA uses the MOVES2014 model to compute onroad source emissions based on model inputs provided by state, local, and tribal air agencies.

Nonroad sources include off-road mobile sources that use gasoline, diesel, and other fuels. Source types include construction equipment, lawn and garden equipment, aircraft ground support equipment, locomotives, and commercial marine vessels. EPA uses the MOVES2014 model to compute nonroad source emissions.

Inventory Analysis

The complete NOx and VOC inventory for this 23-county area is shown in Tables A.2 and A.3. Illinois counties contributed about two thirds of regional ozone precursor emissions (61.5% for NOx, 68.1% for VOC), while Illinois and Indiana counties together accounted for about 80% of regional ozone precursor emissions (80.1% for NOx, 78.5% for VOC). The ten Wisconsin counties (including the greater Milwaukee area) contributed only about 20% of ozone precursor emissions (19.9% for NOx, 21.5% for VOC).

Table A.2. Annual 2014 NOx emissions in tons for the Wisconsin Lake Michigan shoreline counties and the Chicago-Naperville-Elgin, IL-IN-WI Core-Based Statistical Area (CBSA).

County	Point Sources	NonPoint Sources	OnRoad Sources	NonRoad Sources	Total	Percent Contribution to 3-State Area
			Wisconsin			
Door	8.6	135.8	599.8	2,321.6	**3,065.8**	1.0%
Kenosha	2,587.5	469.5	1,765.0	1,195.0	**6,017.0**	2.0%
Kewaunee	50.6	75.7	318.1	694.9	**1,139.3**	0.4%
Manitowoc	814.0	353.4	1,371.5	694.5	**3,233.4**	1.1%
Milwaukee	6,716.2	3,180.7	8,979.6	3,157.3	**22,033.7**	7.2%
Ozaukee	313.1	303.3	1,312.6	1,169.7	**3,098.6**	1.0%
Racine	285.0	671.3	1,848.6	1,340.7	**4,145.6**	1.4%
Sheboygan	1,813.8	589.1	1,383.8	799.6	**4,586.3**	1.5%
Washington	219.3	523.3	1,968.7	888.7	**3,599.9**	1.2%
Waukesha	489.2	1,660.5	5,055.2	2,465.1	**9,669.9**	3.2%
Total	**13,297.2**	**7,962.5**	**24,602.8**	**14,727.0**	**60,589.6**	**19.9%**
			Illinois			
Cook	13,961.9	19,521.9	45,267.2	17,089.0	**95,839.9**	31.5%
DeKalb	127.4	298.0	1,513.8	1,433.5	**3,372.7**	1.1%
DuPage	839.9	4,531.7	12,168.4	4,448.2	**21,988.3**	7.2%
Grundy	1,036.4	167.3	1,029.8	1,347.6	**3,581.0**	1.2%
Kane	551.7	1,997.9	5,566.2	3,187.7	**11,303.5**	3.7%
Kendall	629.9	356.6	1,220.2	833.0	**3,039.8**	1.0%
Lake	2,294.7	3,252.8	8,382.7	3,646.1	**17,576.3**	5.8%
McHenry	220.0	1,181.1	3,479.3	1,771.9	**6,652.4**	2.2%
Will	9,061.8	1,858.9	8,515.3	4,294.9	**23,731.0**	7.8%
Total	**28,723.7**	**33,166.3**	**87,142.9**	**38,051.9**	**187,084.8**	**61.5%**
			Indiana			
Lake	7,191.5	94.4	2,452.2	455.1	**10,193.2**	3.3%
Jasper	15,374.1	1,063.6	8,654.5	3,809.3	**28,901.5**	9.5%
Newton	22.2	46.1	552.9	305.8	**926.9**	0.3%
Porter	10,389.4	362.1	3,307.4	2,579.0	**16,638.0**	5.5%
Total	**32,977.2**	**1,566.2**	**14,967.0**	**7,149.3**	**56,659.7**	**18.6%**
3-State TOTAL	**74,998.1**	**42,695.0**	**126,712.7**	**59,928.2**	**304,334.0**	**100.0%**
Source Type Contribution	**24.6%**	**14.0%**	**41.6%**	**19.7%**	**100.0%**	

Table A.3. Annual 2014 VOC emissions in tons for the Wisconsin Lake Michigan shoreline counties and the Chicago-Naperville-Elgin, IL-IN-WI Core-Based Statistical Area (CBSA).

County	Point Sources	NonPoint Sources	OnRoad Sources	NonRoad Sources	Total	Percent Contribution to 3-State Area
			Wisconsin			
Door	79.8	471.4	356.3	1,531.1	**2,438.6**	1.0%
Kenosha	178.7	1,556.5	908.7	560.8	**3,204.6**	1.4%
Kewaunee	56.5	279.4	188.3	754.7	**1,278.8**	0.5%
Manitowoc	463.5	1,088.9	699.1	556.4	**2,808.0**	1.2%
Milwaukee	1,851.7	8,864.7	4,432.6	1,867.1	**17,016.0**	7.3%
Ozaukee	122.7	876.0	635.6	356.1	**1,990.4**	0.9%
Racine	437.0	2,081.7	951.4	741.1	**4,211.2**	1.8%
Sheboygan	551.1	1,402.8	675.8	777.3	**3,407.0**	1.5%
Washington	281.8	1,613.0	941.6	721.9	**3,558.3**	1.5%
Waukesha	869.3	4,601.8	2,559.6	2,351.2	**10,381.9**	4.4%
Total	**4,891.9**	**22,836.2**	**12,349.0**	**10,217.6**	**50,294.7**	**21.5%**
			Illinois			
Cook	8,070.8	43,789.7	23,981.9	10,148.8	**85,991.2**	36.8%
DeKalb	231.7	1,361.8	839.7	667.3	**3,100.5**	1.3%
DuPage	1,145.3	8,985.9	6,196.5	3,281.8	**19,609.5**	8.4%
Grundy	536.8	737.1	433.5	399.5	**2,106.9**	0.9%
Kane	902.7	4,686.0	2,944.5	1,660.4	**10,193.5**	4.4%
Kendall	215.1	1,125.8	733.7	1,088.4	**3,163.0**	1.4%
Lake	450.1	6,368.2	4,372.4	3,445.7	**14,636.4**	6.3%
McHenry	260.3	2,756.2	1,971.5	1,085.3	**6,073.4**	2.6%
Will	2,415.6	5,984.1	4,094.8	1,866.8	**14,361.3**	6.1%
Total	**14,228.5**	**75,794.7**	**45,568.6**	**23,644.0**	**159,235.8**	**68.1%**
			Indiana			
Lake	209.9	653.2	551.1	389.0	1,803.1	0.8%
Jasper	3,997.2	5,454.0	3,538.1	2,041.2	15,030.5	6.4%
Newton	35.0	483.2	170.8	804.8	1,493.8	0.6%
Porter	743.8	2,189.7	1,209.2	1,823.9	5,966.7	2.6%
Total	**4,985.9**	**8,780.1**	**5,469.3**	**5,058.8**	**24,294.1**	**10.4%**
3-State TOTAL	**24,106.3**	**107,411.0**	**63,386.8**	**38,920.4**	**233,824.5**	**100.0%**
Source Type Contribution	**10.3%**	**45.9%**	**27.1%**	**16.6%**	**100.0%**	

APPENDIX B

Wisconsin Ozone Control Measures

This appendix documents the large number of permanent and enforceable control measures that have been implemented in Wisconsin to reduce NO_x and VOC ozone precursor emissions. These emission control measures have led to dramatic reductions in ozone precursor emissions from Wisconsin's lakeshore counties, as well as from the rest of the state.

1. Point Source Control Measures

1.1. $\underline{NO_x \text{ Control Measures}}$

Wisconsin NO_x Control Program – Wisconsin has implemented a NO_x control program to meet requirements for the 1997 ozone NAAQS. These control requirements are also applicable to the 2008 ozone NAAQS. The control requirements include: 1) Emission limitations to meet Rate-of-Progress (ROP); 2) Reasonable Available Control Technology (RACT) emission limitations for facilities with a current or future potential-to-emit (PTE) of 100 tons or more per year; and, 3) New source NOx performance standards that implement appropriate control technology for new or modified emission units regardless of ROP or RACT applicability. The ROP emission limitations are codified under s. NR 428.05, Wis. Adm. Code; the RACT emission limitations under s. NR 428.22, Wis. Adm. Code; and the new source emission limitations under s. NR 428.04, Wis. Adm. Code. The start date and applicability by county of each element of Wisconsin's NO_x control program is summarized in Table B.1.

Federal NO_x Transport Rules – Beginning January 1, 2009, electric generating units (EGUs) in 22 states east of the Mississippi (including Wisconsin) became subject to ozone season NO_x emission budgets under the Clean Air Interstate Rule (CAIR). CAIR reduces transport of NO_x emissions affecting attainment and maintenance of the 1997 ozone NAAQS as required under Section 110(a)(2)(D) of the Clean Air Act (CAA).[1] The Cross-State Air Pollution Rule (CSAPR) was implemented in 2011 to replace the CAIR requirements. The CSAPR emission reductions began with the 2015 ozone season. In 2016, EPA finalized the CSAPR Update (81 FR 74504) to address NO_x transport affecting the attainment and maintenance of the 2008 ozone NAAQS (79 FR 16436). The CSAPR Update establishes more stringent NO_x budgets starting with the 2017 ozone season. These rules implemented a system of allocating allowances by utility emission unit with provision for limited trading.

[1] The first transport rule promulgated by EPA was the NOx SIP Call in 2003. The EGU requirements are subsumed by the CAIR rule. However, NO_x emissions for some larger industrial sources in states contributing to Wisconsin continue to be regulated under the NO_x SIP Call.

Table B.1. NO_x control program applicability.

County	Applicability and Effective Year		
	ROP - Existing Emission Units (NR 428.05)	RACT – Emission Units at Facilities > 100 TPY PTE (NR 420.22)	New Source Limits for Emission Units (NR 428.04)
Door	--	--	--
Kenosha	2001	2007	2001
Manitowoc	2001	--	--
Milwaukee	2001	2007	2001
Ozaukee	2001	2007	2001
Racine	2001	2007	2001
Sheboygan	2001	2007	--
Washington	2001	2007	2001
Waukesha	2001	2007	2001

Electric Utility NO_x Requirements – EGUs in the counties along Lake Michigan (as well as others in Wisconsin) are well controlled for NO_x emissions. These various EGUs are subject to the discussed Wisconsin NO_x control program, the federal transport rules, new source emission requirements, and limitations under consent decrees entered with EPA. The 2014 emissions and control requirements are listed for coal-fired and combustion turbine EGUs in Tables B.2 and B.3, respectively. The tables identify the EGUs along Lake Michigan, including those in the Milwaukee area.

Table B.2. Control requirements for coal-fired EGU boilers in 2014 and thereafter. Numbers listed in the control requirements column refer to the programs listed in the footnotes. There are no coal-fired EGUs in Door, Washington or Waukesha Counties.

County	Plant	Unit	Emission Rate Limit (lbs/mmBtu)	Control Equipment	Control Requirements	2014 NOx (tons)
Kenosha	Pleasant Prairie	1	0.1	SCR	1,2,3,4	1,081
		2	0.1	SCR	1,2,3,4	1,338
Manitowoc	Manitowoc Public Util.	8	0.2	Fluidized Bed Combustion / Optimization	2,3,5	40
		9	0.155	Fluidized Bed Combustion, SNCR	2,3,5	34
Milwaukee	Valley	1	0.08	2015 Converted to NG	3,4,6	367[a]
		2	0.08	2015 Converted to NG	3,4,6	464[a]
		3	0.08	2015 Converted to NG	3,4,6	325[a]
		4	0.08	2015 Converted to NG	3,4,6	328[a]
	Elm Road	1	0.06	SCR	3,5	1,024
		2	0.06	SCR	3,5	964
	Oak Creek	5	0.1	SCR	1,2,3,4	492
		6	0.1	SCR	1,2,3,4	457
		7	0.1	SCR	1,2,3,4	410
		8	0.1	SCR	1,2,3,4	307
Ozaukee	--	--	--	--	--	--
Racine	--	--	--	--	--	--
Sheboygan	Edgewater	3	Retired	Retired	1,2,3,4	0
		4	0.1	LNB, SNCR	1,2,3,4	1,278[b]
		5	0.08 (30-day) 0.07 (12 month)	SCR	1,2,3,4	361

1) Wisconsin NO_x RACT program
2) Wisconsin NO_x ROP program
3) Federal CSAPR and CSAPR Update Transport programs
4) Federal Consent Decree
5) Best Available Control Technology (BACT)
6) Wisconsin NO_x New Source Performance Standards

a) The Valley Plant units 1,2,3, and 4 began firing natural gas in 2015. The 2016 NOx emissions are 64, 61, 92, and 91 tons for each unit, respectively.
b) Alliant Energy is required under federal consent decree to either retire Edgewater 4 or fire only natural gas beginning in 2019.
Definitions: NG – natural gas; LNB – low NOx burner; SCR – selective catalytic reduction; SNCR – selective non-catalytic reduction.

Table B.3. Control requirements for combustion turbine EGUs in 2014 and thereafter. There are no combustion turbines in Door or Waukesha Counties.

County	Plant	Unit	Emission Rate Limit (lbs/ mmBtu)	Control Equipment	Control Requirements	2014 NOx (tons)
Kenosha	Paris	1, 2, 3, 4	NG – 25 ppmdv	WI	3	12.5
Manitowoc	--	--	--	--	--	--
Milwaukee	--	--	--	--	--	--
Ozaukee	Port Washington	11,12, 21,22	NG - 3 ppmdv	DLN	1,2	127.9
Racine	--	--	--	--	--	--
Sheboygan	Sheboygan Falls	1, 2	NG - 25 ppmdv	DLN	3	2.3
Washington	Germantown	1, 2, 3, 4	Oil - 65 ppmdv	WI	3	103.5
		5	NG – 20 ppmdv	DLN	1	0.4

1) Best Available Control Technology (BACT)
2) New Source Performance Standards (NSPS)
3) Wisconsin NO_x RACT program

Definitions: ppmdv – parts per million dry volume; WI – water injection; and, DLN – Dry Low NOx burner.

1.2. Wisconsin VOC Control Measures

VOC RACT/CTG – Wisconsin has implemented VOC RACT to fulfill control technology guideline (CTG) requirements for the Wisconsin nonattainment areas under the 1997 and 2008 ozone NAAQS. These VOC RACT/CTG requirements are codified under chapters NR 419 through 424, Wis. Adm. Code. The list of the CTGs in place in Wisconsin is provided in Table B.4. All of these CTG requirements were implemented and effective prior to 2011.

1.3. Federal VOC Control Measures for Point Sources

A number of federal NESHAP rules have been implemented to control hazardous pollutants. These rules include requirements to control hazardous organic pollutants through ensuring complete combustion of fuels or implementing requirements for emissions of total hydrocarbons. Under either approach, the rules act to reduce total VOC emitted by the affected sources. These NESHAP rules apply to both major and area source facilities. Major sources are those facilities emitting more than 10 tons per year of a single hazardous air pollutant or more than 25 tons per year of all hazardous air pollutants in total. Area sources are those facilities that emit less than the major source thresholds for hazardous air pollutants.

These NESHAP measures apply nationally, thereby reducing the transport of VOC emissions. The NESHAP rules that will likely contribute to VOC emission reductions in the 2017 ozone season include the following:

- *Mercury and Air Toxics (MATS) NESHAP* – On February 16, 2012, EPA promulgated the MATS rule under part 63 subpart UUUUU. Emission and other requirements were fully applicable by April 16, 2015.
- *Major Source Industrial, Commercial, and Institutional (ICI) Boiler and Process Heater NESHAP* – On March 21, 2011, EPA promulgated the "National Emission Standards for Hazardous Air Pollutants for Major Sources: Industrial, Commercial, and Institutional Boilers and Process Heaters" under part 63 subpart DDDDD. Emission and other requirements were fully applicable by January 31, 2016.
- *Area Source (non-major point sources) ICI Boiler and Process Heater NESHAP* – On March 21, 2011 EPA promulgated the "National Emission Standards for Hazardous Air Pollutants for Area Sources: Industrial, Commercial, and Institutional Boilers" under part 63 subpart JJJJJJ. This NESHAP requires solid fuel and oil fuel fired boilers operated by sources that are below the major source threshold to begin periodic combustion tuning by March 21, 2014.
- *Internal Combustion Engine Rules* – EPA has promulgated three rules that limit the total amount of hydrocarbon emissions from internal combustion engines:
    - National Emission Standards for Hazardous Pollutants for Reciprocating Internal Combustion Engines (RICE Maximum Achievable Control Technology, MACT) was promulgated on June 15, 2004 under Part 63, subpart ZZZZ and revised in January 2008 and March 2010, with the two revisions impacting additional RICE units;
    - Standards of Performance for Stationary Spark Ignition Internal Combustion Engines promulgated on January 18, 2008 under Part 60, subpart JJJJ; and
    - Standards of Performance for Stationary Compression Ignition Internal Combustion Engines promulgated on July 11, 2006 under Part 60, subpart IIII.

  These rules implement hydrocarbon emission limitations prior to and after 2011 based on compliance dates. These rules also act to continuously reduce emissions as existing stationary engines are replaced by new, cleaner-burning engines.

2. Area Source Control Measures

2.1. Area Source VOC Control Measures

As noted for point sources, Wisconsin has implemented a number of VOC RACT/CTG rules under chs. NR 419 through 424, Wis. Adm. Code. A number of these rules limit VOC emissions from area sources as well, as noted in Table B.4. In addition to Stage 1 fuel delivery vapor controls (the loading of underground storage tanks at gas stations), Wisconsin previously had a Stage 2 vehicle refueling vapor recovery program in place. However, the Stage 2 program was removed from Wisconsin's ozone SIP on November 4, 2013 (78 FR 65875) with EPA approval because the equipment was found to interface negatively with the onboard vapor recovery systems required on gasoline fueled new vehicles after 1998. As stage 2 equipment was removed, refueling facility VOC emissions decreased slightly due to reduced fugitive underground storage tank VOC venting. This SIP revision was based on a technical showing of net benefit as required under CAA Sections 110(l) and 193 in order to prevent SIP backsliding.

Table B.4. Volatile Organic Compounds (VOC) Control Technique Guidelines incorporated into Wisconsin Administrative Code.

Source	Title (Description)	EPA CTG Report No.	Wis. Adm. Code Incorporation	Emissions Inventory Classification
Petroleum and Gasoline Sources				
Bulk Gasoline Plants	Control of Volatile Organic Emissions from Bulk Gasoline Plants [bulk gasoline plant unloading, loading and storage]	EPA-450/2-77-035	NR 420.04(2)	Stationary Point Source
Refinery Equipment - Vacuum Producing Systems, Wastewater Separators, and Process Unit Turnarounds	Control of Refinery Vacuum Producing Systems, Wastewater Separators, and Process Unit Turnarounds	EPA-450/2-77-025	NR 420.05(1), (2) and (3)	Stationary Point Source
Refinery Equipment - Control of VOC Leaks	Control of Volatile Organic Compound Leaks from Petroleum Refinery Equipment	EPA-450/2-78-036	NR 420.05(4)	Stationary Point Source
Refinery Equipment - Control of VOC Leaks	Control of Volatile Organic Compound Equipment Leaks from Natural Gas/Gasoline Processing Plants	EPA-450/3-83-007	NR 420.05(4)	Stationary Point Source
Tanks - Fixed Roof	Control of Volatile Organic Emissions from Storage of Petroleum Liquids in Fixed-Roof Tanks	EPA-450/2-77-036	NR 420.03(5)	Stationary Point Source
Tanks - External Floating Roofs	Control of Volatile Organic Emissions from Petroleum Liquid Storage in External Floating Roof Tanks	EPA-450/2-78-047	NR 420.03(6) and (7)	Stationary Point Source
Gasoline Loading Terminals	Control of Hydrocarbons from Tank Truck Gasoline Loading Terminals	EPA-450/2-77-026	NR 420.04(1)	Stationary Point Source
Tank Trucks	Control of Volatile Organic Compound Leaks from Gasoline Tank Trucks and Vapor Collection Systems	EPA-450/2-78-051	NR 420.04(4)	Stationary Area Source
Gasoline Delivery - Stage I Vapor Control Systems	Design Criteria for Stage I Vapor Control Systems – Gasoline Service Stations	EPA-450/R-75-102	NR 420.04(3)	Stationary Area Source

Source	Title (Description)	EPA CTG Report No.	Wis. Adm. Code Incorporation	Emissions Inventory Classification
Surface Coating				
Automobile & Light-duty Truck	Control Techniques Guidelines for Automobile and Light-Duty Truck Assembly Coatings	EPA 453/R-08-006	NR 422.09	Stationary Point Source
Cans	Control of Volatile Organic Emissions from Existing Stationary Sources – Volume II: Surface Coating of Cans, Coils, Paper, Fabrics, Automobiles, and Light-Duty Trucks	EPA-450/2-77-008	NR 422.05	Stationary Point Source
Coils	Control of Volatile Organic Emissions from Existing Stationary Sources – Volume II: Surface Coating of Cans, Coils, Paper, Fabrics, Automobiles, and Light-Duty Trucks	EPA-450/2-77-008	NR 422.06	Stationary Point Source
Fabric & Vinyl	Control of Volatile Organic Emissions from Existing Stationary Sources – Volume II: Surface Coating of Cans, Coils, Paper, Fabrics, Automobiles, and Light-Duty Trucks	EPA-450/2-77-008	NR 422.08	Stationary Point Source
Flat Wood Paneling	Control of Volatile Organic Emissions from Existing Stationary Sources – Volume VII: Factory Surface Coating of Flat Wood Paneling	EPA-450/2-78-032	NR 422.13	Stationary Point Source
	Control Techniques Guidelines for Flat Wood Paneling Coatings	EPA-453/R-06-004	NR 422.131	Stationary Point Source
Large Appliances	Control of Volatile Organic Emissions from Existing Stationary Sources – Volume V: Surface Coating of Large Appliances	EPA-450/2-77-034	NR 422.11	Stationary Point Source
	Control Techniques Guidelines for Large Appliance Coatings	EPA 453/R-07-004	NR 422.115	Stationary Point Source
Magnet Wire	Control of Volatile Organic Emissions from Existing Stationary Sources – Volume IV: Surface Coating of Insulation of Magnet Wire	EPA-450/2-77-033	NR 422.12	Stationary Point Source
Metal Furniture	Control of Volatile Organic Emissions from Existing Stationary Sources – Volume III: Surface Coating of Metal Furniture	EPA-450/2-77-032	NR 422.1	Stationary Point Source

Source	Title (Description)	EPA CTG Report No.	Wis. Adm. Code Incorporation	Emissions Inventory Classification
	Control Techniques Guidelines for Metal Furniture Coatings	EPA 453/R-07-005	NR 422.105	Stationary Point Source
Metal Parts, miscellaneous	Control Techniques Guidelines for Miscellaneous Metal and Plastic Parts Coatings	EPA 453/R-08-003	NR 422.15	Stationary Point Source
	Fire Truck and Emergency Response Vehicle Manufacturing - surface coating	(covered under Misc. Metal Parts CTG)	NR 422.151	Stationary Point Source
Paper, Film and Foil	Control of Volatile Organic Emissions from Existing Stationary Sources – Volume II: Surface Coating of Cans, Coils, Paper, Fabrics, Automobiles, and Light-Duty Trucks	EPA-450/2-77-008	NR 422.07	Stationary Point Source
	Control Techniques Guidelines for Paper, Film, and Foil Coatings	EPA 453/R-07-003	NR 422.075	Stationary Point Source
Plastic Parts - Coatings	Control Techniques Guidelines for Miscellaneous Metal and Plastic Parts Coatings	EPA 453/R-08-003	NR 422.083	Stationary Point Source
Traffic Markings	Reduction of Volatile Organic Compound Emissions from the Application of Traffic Markings	EPA-450/3-88-007	NR 422.17	Stationary Area Source
Wood Furniture	Control of Volatile Organic Compound Emissions from Wood Furniture Manufacturing Operations	EPA-453/R-96-007	NR 422.125	Stationary Point Source
Graphic Arts				
Rotogravure & Flexography	Control of Volatile Organic Emissions from Existing Stationary Sources – Volume VIII: Graphic Arts-Rotogravure and Flexography	EPA-450/2-78-033	NR 422.14	Stationary Point Source
Flexible Packaging	Control Techniques Guidelines for Flexible Package Printing	EPA-453/R-06-003	NR 422.141	Stationary Point Source
Letterpress	Control Techniques Guidelines for Offset Lithographic Printing and Letterpress Printing	EPA-453/R-06-002	NR 422.144	Stationary Point Source

Source	Title (Description)	EPA CTG Report No.	Wis. Adm. Code Incorporation	Emissions Inventory Classification
Lithographic	Control Techniques Guidelines for Offset Lithographic Printing and Letterpress Printing	EPA-453/R-06-002	NR 422.142 and 422.143	Stationary Point Source
Solvents				
Dry Cleaning	Control of Volatile Organic Emissions from Perchloroethylene Dry Cleaning Systems	EPA-450/2-78-050	NR 423.05	Stationary Area Source
	Control of Volatile Organic Compound Emissions from Large Petroleum Dry Cleaners	EPA-450/3-82-009	NR 423.05	Stationary Area Source
Industrial Cleaning	Control Techniques Guidelines for Industrial Cleaning Solvents	EPA-453/R-06-001	NR 423.035 and 423.037	Stationary Area Source
Metal Cleaning	Control of Volatile Organic Emissions from Solvent Metal Cleaning	EPA-450/2-77-022	NR 423.03	Stationary Area Source
Chemical				
Pharmaceutical	Control of Volatile Organic Emissions from Manufacture of Synthesized Pharmaceutical Products	EPA-450/2-78-029	NR 421.03	Stationary Point Source
Polystyrene	Control of Volatile Organic Compound Emissions from Manufacture of High-Density Polyethylene, Polypropylene, and Polystyrene Resins	EPA-450/3-83-008	NR 421.05	Stationary Point Source
Rubber	Control of Volatile Organic Emissions from Manufacture of Pneumatic Rubber Tires	EPA-450/2-78-030	NR 421.04	Stationary Point Source
Synthetic Organic	Control of Volatile Organic Compound Emissions from Air Oxidation Processes in Synthetic Organic Chemical Manufacturing Industry	EPA-450/3-84-015	NR 421.07	Stationary Point Source
Synthetic Organic	Control of Volatile Organic Compound Emissions from Reactor Processes and Distillation Operations in Synthetic Organic Chemical Manufacturing Industry	EPA-450/4-91-031	NR 421.07	Stationary Point Source

Source	Title (Description)	EPA CTG Report No.	Wis. Adm. Code Incorporation	Emissions Inventory Classification
Synthetic Resin	Control of Volatile Organic Compound Leaks from Synthetic Organic Chemical Polymer and Resin Manufacturing Equipment	EPA-450/3-83-006	NR 421.05	Stationary Point Source
Manufacturing				
Asphalt	Control of Volatile Organic Emissions from Use of Cutback Asphalt	EPA-450/2-77-037	NR 422.16	Stationary Area Source

There are also a number of federal programs in place which reduce area source VOC emissions. VOC emission standards for consumer and commercial products were promulgated under 40 CFR Part 59. This program was implemented prior to 2011 and will continue to maintain reduced VOCs emitted from this source category. Future emission levels will vary depending on population and activity use factors. Another federal rule, the area source hazardous air pollutant control rule, also controls area VOC emissions associated with fuel storage and transfer activities (40 CFR 63, Subpart R, BBBBBB, and CCCCCC).

3. Onroad Source Control Measures

Both NO_x and VOC emissions from onroad mobile sources are substantially controlled through federal new vehicle emission standards programs and fuel standards that impact both tailpipe emissions and evaporative losses. Although initial compliance dates in many cases were prior to 2011, these regulations have continued to reduce area-wide emissions as fleets turn over to newer vehicles. All of these programs apply nationally and have reduced ozone precursor emissions contributing to ozone transport. The federal programs contributing to reductions in onroad ozone precursor emissions include those listed in Table B.5.

Table B.5. Federal onroad mobile source regulations contributing to attainment.

On-road Control Program	Pollutants	Model Year[a]	Regulation
Passenger vehicles, SUVs, and light duty trucks – emissions and fuel standards	VOC & NO_x	2004 – 2009+ (Tier 2) 2017+ (Tier 3)	40 CFR Part 85 & 86
Light-duty trucks and medium duty passenger vehicle – evaporative standards	VOC	2004 - 2010	40 CFR Part 86
Heavy-duty highway compression engines	VOC & NO_x	2007+	40 CFR Part 86
Heavy-duty spark ignition engines	VOC & NO_x	2005 – 2008+	40 CFR Part 86
Motorcycles	VOC & NO_x	2006 – 2010 (Tier 1 & 2)	40 CFR Part 86
Mobile Source Air Toxics – fuel formulation, passenger vehicle emissions, and portable container emissions	Organic Toxics & VOC	2009 – 2015[b]	40 CFR Part 59, 80, 85, & 86
Light duty vehicle corporate average fuel economy standards	Fuel efficiency (VOC and NO_x)	2012-2016 & 2017-2025	40 CFR Part 600

[a] The range in model years affected can reflect phasing of requirements based on engine size or initial years for replacing earlier tier requirements.
[b] The range in model years reflects phased implementation of fuel, passenger vehicle, and portable container emission requirements as well as the phasing by vehicle size and type.

Two additional ongoing CAA-required programs limit onroad VOC and NO_X emissions. The first program, administered by EPA, has required the use of reformulated gasoline (RFG) in southeast Wisconsin (Kenosha, Milwaukee, Ozaukee, Racine, Washington and Waukesha counties) and the Chicago area since 1995. The second program is the Wisconsin-administered inspection/maintenance (I/M) program and is required for southeast Wisconsin (Kenosha, Milwaukee, Ozaukee, Racine, Washington and Waukesha counties) and Sheboygan County. The Wisconsin I/M program was first implemented in 1984 and has gone through several modifications and enhancements since that time. The I/M program requirements are codified in ch. NR 485, Wis. Adm. Code. Both the RFG and the I/M programs reduce average vehicle VOC and NO_X emissions and garner some level of continued incremental reduction as fleets turn over to new vehicles.

4. Nonroad Control Measures

Similar to on-road sources, VOC and NO_X emitted by nonroad mobile sources are significantly controlled via federal standards for new engines and therefore reduce ozone precursor emissions. Table B.6 lists the nonroad source categories and applicable federal regulations. The nonroad regulations continue to slowly lower average unit and total sector emissions as equipment fleets are replaced each year (it takes approximately 20 years for complete fleet turnover), pulling the highest emitting equipment out of circulation or substantially reducing its use. The new engine requirements are implemented in conjunction with fuel programs regulating fuel sulfur content. The fuel programs enable achievement of various new engine tier VOC and NO_X emission limits.

The RFG program noted in the onroad control measures also contributes to lower NOx and VOC emissions from the nonroad mobile sector.

Table B.6. Federal nonroad mobile source regulations contributing to attainment.

Nonroad Control Program	Pollutants	Model Year[a]	Regulation
Aircraft	HC & NO_x	2000 – 2005+	40 CFR Part 87
Compression Ignition[b]	NMHC & NO_x	2000 – 2015+ (Tier 4)	40 CFR Part 89 & 1039
Large Spark Ignition	HC & NO_x	2007+	40 CFR Part 1048
Locomotive Engines	HC & NO_x	2012 – 2014 (Tier 3) 2015+ (Tier 4)	40 CFR Part 1033
Marine Compression Ignition	HC & NO_x	2012 – 2018	40 CFR Part 1042
Marine Spark Ignition	HC & NO_x	2010+	40 CFR Part 1045
Recreational Vehicle[c]	HC & NO_x	2006 – 2012 (Tier 1 – 3) (phasing dependent on vehicle type)	40 CFR Part 1051
Small Spark Ignition Engine < 19[d] Kw – emission standards	HC & NO_x	2005 – 2012 (Tier 2 & 3) (phasing based on both Tier and engine size)	40 CFR Part 90 & 1054
Small Spark Ignition Engine < 19 Kw – evaporative standards	HC & NO_x	2008 – 2016 (phasing based on both engine size and category)	40 CFR Part 1045, 54, & 60

HC – Hydrocarbon (VOCs)

NMHC – Non-Methane Hydrocarbon (VOCs)

[a] The range in model years affected can reflect phasing of requirements based on engine size or initial years for replacing earlier tier requirements.

[b] Compression ignition applies to diesel non-road compression engines including engines operated in construction, agricultural, and mining equipment.

[c] Recreational vehicles include snowmobiles, off-road motorcycles, and all-terrain vehicles.

[d] Small spark ignition engines include engines operated in lawn and hand-held equipment.

APPENDIX C

Supplemental Analyses of Ozone Monitoring Data

2015 Ozone NAAQS Area Designations Technical Support Document
Wisconsin Department of Natural Resources – April 2017

This appendix presents additional analyses in support of the technical support document (TSD) submitted by the Wisconsin Department of Natural Resources related to 2015 ozone National Ambient Air Quality Standards (NAAQS) designations. These supplemental analyses include:

1. Additional comparison of hourly ozone data at the inland and lakeshore monitors.
2. Analysis of the lake breeze phenomenon. This section discusses in greater detail the methodology applied in the TSD to classify high-ozone events. It also presents and discusses the average ozone concentration and wind direction profiles for each event type.
3. Evidence for direct overland transport of ozone to the inland Kenosha County monitor. This section shows examples of days during which this transport occurred and discusses the patterns involved in such transport.

1. Comparison of hourly ozone data at the inland and lakeshore monitors

Section 4.2.2 of the TSD analyzes hourly ozone concentrations at the inland and lakeshore monitors in Sheboygan and Kenosha counties. This analysis found that 1-hour ozone concentrations at both inland monitors were generally lower than those monitored at the lakeshore, and these concentration differences were greatest when lakeshore ozone concentrations were at their highest. Figure 4.5 of the TSD uses a simple scatterplot to compare data at the inland and lakeshore monitors. This section uses boxplots to analyze the same hourly ozone concentration data in different ways.

Figure C.1 shows 1-hour average ozone concentrations at the inland monitors in Sheboygan and Kenosha counties plotted versus those at the lakeshore monitors for the same hours. The data are plotted three ways:

1) As a scatterplot.
2) As a boxplot, including all measurements available.
3) As a boxplot, showing only the hours with ozone concentrations above 70 ppb at the lakeshore monitor.

The two scatterplots at the top of Figure C.1 are also shown in Figure 4.5 of the TSD and discussed therein. The main conclusions from these graphs are that inland ozone concentrations increase as lakeshore concentrations increase, but are consistently lower than lakeshore concentrations. In particular:

- For Sheboygan County, a best-fit line through the data has a slope of 0.79 and a y-intercept close to zero, meaning that inland concentrations are roughly 79 percent of lakeshore concentrations.

- For Kenosha County, the slope of the best-fit line is 0.89, and the intercept is very close to zero, meaning that the average inland concentrations are roughly 89 percent of lakeshore concentrations.

The largest differences were observed at the highest concentrations, and differences were greatest in Sheboygan County.

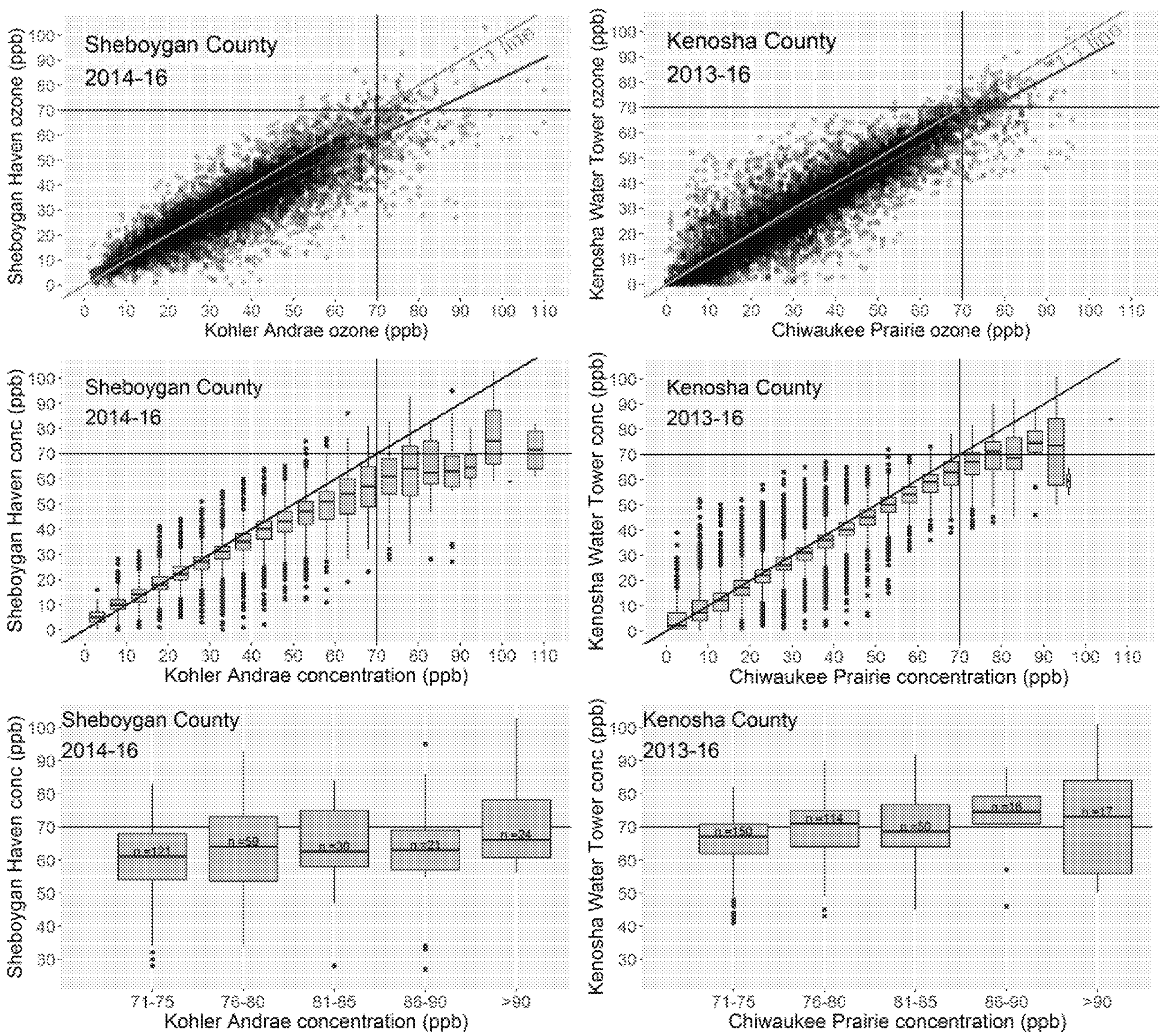
The remaining graphs of Figure C.1 plot this same 1-hour average concentration data as boxplots. In these plots, the observations are grouped together into bins according to the lakeshore ozone concentration. For example, one bin includes all of the observations for lakeshore ozone concentrations between 71 and 75 ppb. For all of the observations within each lakeshore concentration bin, the median inland concentration is shown as the line in the middle of each box. The box itself encloses the middle half of all inland ozone concentrations (from the 25th to the 75th percentile values). The lines and points above and below the box show the inland ozone concentrations values that are above or below the range in the box.[1]

Boxplots can be very useful for analyzing large amounts of data because they group and summarize that data in ways that make it easier to visualize trends in a statistically rigorous way. For example, in the scatterplots at the top of Figure C.1, it is impossible to see the most frequently observed inland concentrations at lakeshore concentrations below 60 ppb because of the large number of overlapping points. In contrast, the boxplots in the middle clearly show the midpoint, middle range of values and entire range of values for each lakeshore concentration bin.

The middle graphs in Figure C.1 show boxplots for all measurements available. These plots show that, particularly at lower concentrations, the middle half of the inland observed concentrations fall within a narrow range of values. For example, for Sheboygan County, during hours with lakeshore concentrations of 31 to 35 ppb, the middle half of inland concentrations ranged from 28 to 33 ppb. This demonstrates that inland and lakeshore concentrations are closely coupled when ozone concentrations are low. However, it is notable that even at these low concentrations, inland ozone concentrations tend to be 2-3 ppb lower than those at the lakeshore. These graphs show the mostly linear increase in inland concentrations compared with lakeshore concentration at lower concentrations. It is also clear from these graphs that, at higher ozone concentrations, the concentration differences between inland and lakeshore monitors become quite large. The differences between inland and lakeshore concentrations during hours with high ozone at the lakeshore are especially large in Sheboygan County.

[1] For example, when the lakeshore Kohler Andrae monitor in Sheboygan County measured between 71 and 75 ppb, the median concentration at the inland Sheboygan Haven monitor was 61 ppb. Half of the monitored inland concentrations in this lakeshore concentration bin fell between 54 ppb and 63 ppb. The lowest inland concentration observed when lakeshore concentrations were between 71 ppb and 75 ppb was 28 ppb, and the highest was 83 ppb.

Figure C.1. Plots of 1-hour ozone concentrations comparing inland monitors to lakeshore monitors in Sheboygan and Kenosha counties. Plots are shown as scatterplots of concentrations for individual hours (top row), boxplots[2] of all hourly concentrations binned based on lakeshore concentrations (middle row), and boxplots of hourly concentrations for lakeshore concentrations above 70 ppb (bottom row). The blue lines in the top four plots show the 1:1 line. The red lines in the top two plots shows the best-fit line to the data. The values in the boxes in the bottom two plots list the number of observations in each lakeshore concentration bin.



[2] Boxplots show the median and range of inland concentrations observed for a bin of lakeshore concentrations. The line in the middle of the box shows the median concentration, and the box encloses the middle half of the concentrations (e.g., the 25th to the 75th percentile values). The "whiskers" extend to the highest or lowest value within 1.5 times the interquartile mean (the difference between the 25th and 75th percentile values) beyond the box. The points are outliers that fall beyond the whiskers.

The bottom graphs in Figure C.1 focus on the inland-lakeshore ozone concentration relationships during high ozone hours. These graphs show only the hours when lakeshore ozone concentrations were above 70 ppb. When lakeshore ozone concentrations were above 70 ppb in Sheboygan County, the median inland concentrations remained steady at around 61 to 66 ppb. This was true even for the highest lakeshore concentrations. For the 24 individual ozone episode hours when lakeshore ozone concentrations were greater than 90 ppb, the median inland concentration was only 66 ppb. A similar relationship is shown for the Kenosha County monitors. The extent of the "whiskers" and points that fall above the boxes indicate that high 1-hour ozone concentrations occasionally occurred at the inland monitors. However, inland ozone concentrations were most frequently decoupled from lakeshore concentrations when lakeshore ozone concentrations were at their highest.

2. Analysis of the Lake Breeze Phenomenon

Section 4.3 of the TSD discusses the impacts of different types of high-ozone events on peak ozone concentrations at inland and lakeshore monitors. This section describes the approach used to classify these events and provides more information about how ozone concentrations and wind direction change during each type of events.

High-ozone events were classified into one of three categories:

- "Deep" lake breeze, meaning a day on which the lake breeze affected both the lakeshore and inland monitors.
- "Shallow" lake breeze, meaning a day on which the lake breeze affected the lakeshore monitor but not the inland monitor.
- No lake breeze, meaning a day with no apparent lake breeze.

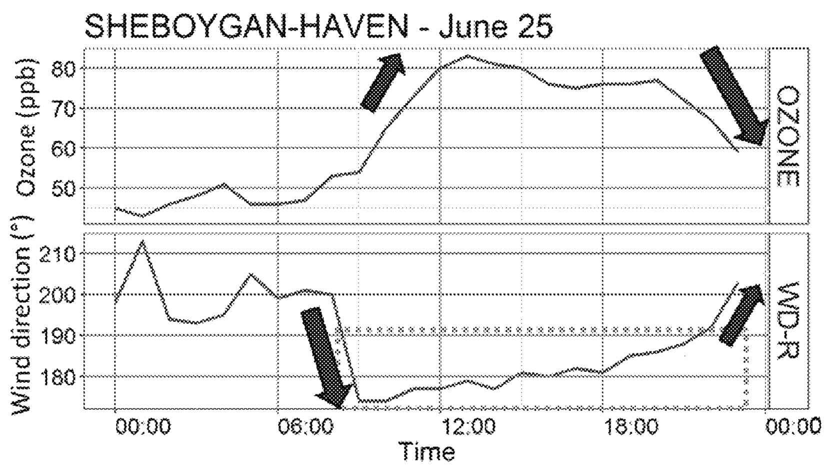
A small number of days could not be classified because of complex patterns.

2.1. Methodology

High-ozone events were identified as days with 1-hour ozone concentrations above 70 ppb. All days with ozone monitoring data at both the lakeshore and inland monitors in a county were considered for the analysis. This includes three ozone seasons for the Sheboygan County monitors (2014-2016) and four ozone seasons for the Kenosha County monitors (2013-2016).

Identification of patterns in wind direction at the inland and lakeshore monitors was the primary means of classification of high-ozone events. Days with a lake breeze typically begin with winds from the southwest during the early morning hours. These wind directions typically shift abruptly to come from a more southerly or southeasterly direction, as shown in Figure C.2. This shift typically occurs in the morning at the lakeshore monitors and later in the day at the inland monitors. The lake breeze may occur for anywhere from a few minutes to 15 or more hours.[3] At the conclusion of a lake breeze event, winds usually revert to their original southwesterly direction unless the lake breeze event is ended by a synoptic wind shift such as a frontal passage. Monitored ozone concentrations tend to increase after the lake breeze reaches a monitor and typically drop sharply when the lake breeze ceases. The presence or absence of these wind shifts was the primary means of identifying the type of events that occurred. During “deep” lake breeze events, these shifts occurred at both inland and lakeshore monitors, whereas on “shallow” lake breeze days, they only occurred at the lakeshore monitor. Such shifts were absent on days without a lake breeze.

Figure C.2. Hourly ozone concentrations (top) and wind directions (bottom) for an example day (June 25, 2016) at the Sheboygan Haven monitor.[4] The red arrows show the onset and cessation of the lake breeze and when ozone concentrations rose and declined steeply. The blue box encloses the hours with a lake breeze.



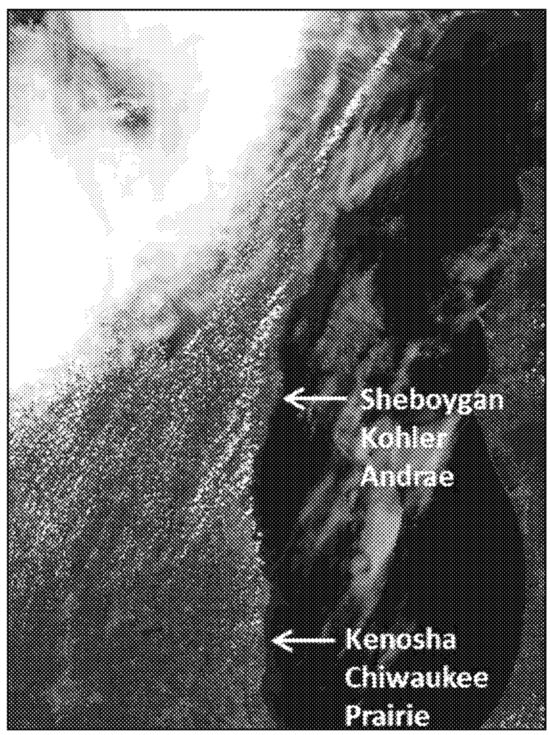
Moderate Resolution Imaging Spectroradiometer (MODIS) satellite images[5] were used to confirm lake breeze event types derived from the wind direction data. The MODIS satellite passes over the Lake Michigan region around 2:30 pm daily and collects visual images of the landscape. On days with a lake breeze and light cloud cover, lake breeze “fronts” can be seen as the interface between areas of clear skies towards the lake and light cloud cover to the west. The clear area is the area experiencing a lake breeze. On days with heavy cloud cover or no cloud cover, MODIS images cannot identify the presence or absence of a lake breeze front.

[3] This classification scheme only counted as “lake breeze” a wind pattern that held for at least 2-3 hours.
[4] Note that hours of the day are listed in Central Standard Time (CST), not in Central Daylight Time (CDT), and are listed under the time at the beginning of the collection period. For example, 1-hour average ozone listed for 1:00 pm CST includes ozone observations collected from 2:00 pm – 2:59 pm CDT.
[5] MODIS images were downloaded from http://ge.ssec.wisc.edu/modis-today/index.php.

The MODIS image in Figure C.3 shows a definite lake breeze in Sheboygan County and a probable narrow lake breeze in Kenosha County. It is notable that days with a shallow lake breeze did not show any obvious lake breeze in the MODIS images. If the lake breeze classification was not conclusive from the wind and MODIS data or if wind data was missing, additional confirmation was provided by examination of the synoptic meteorology of that day or from wind patterns at nearby airports or air quality monitors.

The distribution of high-ozone events determined by these classifications is shown in Table 4.1 of the TSD.

Figure C.3. MODIS satellite image for the afternoon of August 4, 2016 showing a definite lake breeze at Sheboygan and a likely lake breeze at Kenosha.



2.2. Ozone Concentration and Wind Direction Profiles for High-Ozone Event Types

Figure C.4 shows ozone concentration and wind direction profiles for each event type. These profiles show the averages (mean) values for all days in that event class. The average ozone concentration profiles were similar for all three classes of events at the lakeshore monitors. These profiles showed peak mean ozone concentrations of 69 ppb to 79 ppb in the afternoon. The highest mean peak lakeshore ozone concentrations were observed during shallow lake breeze events and the lowest during events without a lake breeze. However, the differences between these events were relatively small.

In contrast, ozone concentration profiles at the inland monitors varied dramatically between different types of events (Figure C.4). The greatest ozone concentrations at the inland monitors were observed during the deep lake breeze events. Shallow lake breeze events resulted in extremely low average peak mean inland ozone concentrations (52-60 ppb) when the peak lakeshore concentrations averaged 77 to 79 ppb – a concentration difference of 17 to 27 ppb. Inland concentrations were low for events without a lake breeze in Sheboygan County, but were relatively high for this type of event in Kenosha County. Overall, average inland concentrations tended to be higher at the inland Kenosha monitor relative to the Sheboygan monitor, as found in Section 4.2 of the TSD. These conclusions are consistent with those drawn based on Figure 4.6 in the TSD, which shows peak 1-hour ozone concentrations separated by ozone event type.

Figure C.4. Plots of mean hourly ozone concentrations (in ppb) and wind direction ("wd", in degrees) for Sheboygan County (left) and Kenosha County (right) monitors for high-ozone episodes with a deep lake breeze (top), a shallow lake breeze (middle), and no lake breeze (bottom).[4] Values for the lakeshore monitor are shown in blue and those for the inland monitor in green.

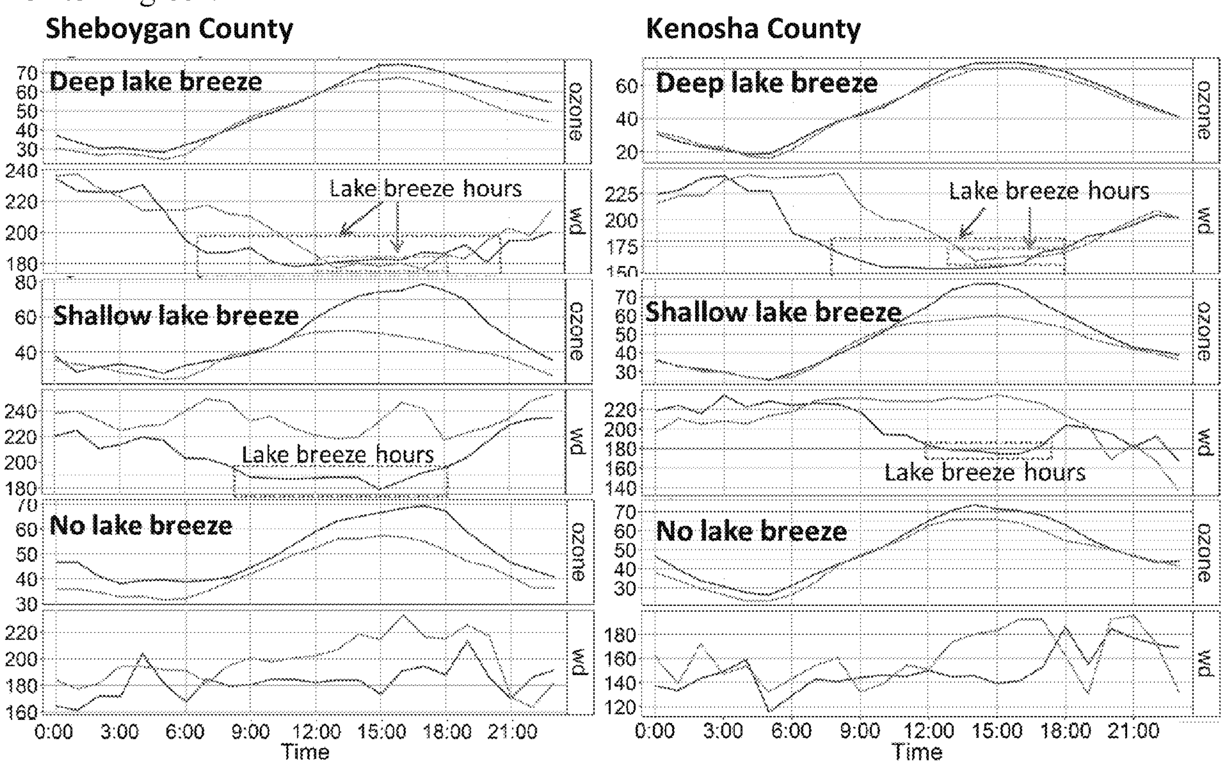


Figure C.4 also shows the wind shifts described earlier for lake breeze events. Events without a lake breeze typically had steady winds from the south (Sheboygan) or southeast (Kenosha) at the lakeshore monitor, although the wind patterns during events in this category were more variable than those in the other two.

During deep lake breeze events, the lower ozone concentrations at the inland monitors likely resulted from dilution of ozone-rich air via mixing with cleaner overlying air as the air moved inland from the lakeshore. Reaction of the ozone with surfaces on land also likely reduced ozone concentrations. On days with a shallow lake breeze, the ozone-enriched air from over the lake never even reached the inland monitor. Ozone concentrations at the inland monitors during most shallow lake breeze events may therefore reflect ozone concentrations in the absence of the influence of Lake Michigan.

3. Direct Overland Transport to the Inland Kenosha County Monitor

In addition to receiving ozone-enriched air via the lake breeze, the inland Kenosha Water Tower monitor also received some ozone via direct transport over land from the Chicago area. This transport was referred to in Section 4.3 of the TSD and is presented and discussed in greater detail here.

For the purposes of this analysis relative to the 2015 ozone NAAQS, days with direct overland transport were determined to be those days when ozone concentrations at the Kenosha Water Tower monitor were above 70 ppb during hours when the wind was coming from the south to southwest (e.g., from over the greater Chicago area), rather than from over the lake.[6] Over the four years that ozone was monitored at the Kenosha Water Tower monitor, five days met this criteria.[7] Of these five identified direct transport days, three were shallow lake breeze events and two were deep lake breeze events. On the days with a deep lake breeze, direct overland transport occurred prior to the onset of the lake breeze at the inland Kenosha Water Tower monitor.

HYSPLIT back trajectories for two of these direct transport days (June 19 and August 4, 2016) show that air parcels passed over much of the Chicago area prior to reaching the Kenosha Water Tower monitor (Figure C.5). Back trajectories for these days are shown as examples. During all five of the identified days, the air arrived at this monitor from the south-southwest to southwest (generally 210° to 230°) during the hours when direct transport was observed.

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[6] The Chicago-Naperville-Joliet Metropolitan Statistical Area includes 9 counties in northeast Illinois, four counties in northwestern Indiana and Kenosha County in Wisconsin.

[7] However, wind data was not collected at this site during 2013 and half of 2015. It is possible additional direct transport days would have been identified had this data been available.

Figure C.5. HYSPLIT back-trajectories for the inland Kenosha Water Tower monitor on two days with direct transport of ozone from the Chicago area. Back trajectories ended at two different elevations above ground level (in meters, m) at 1 PM and were projected backwards for 48 hours.

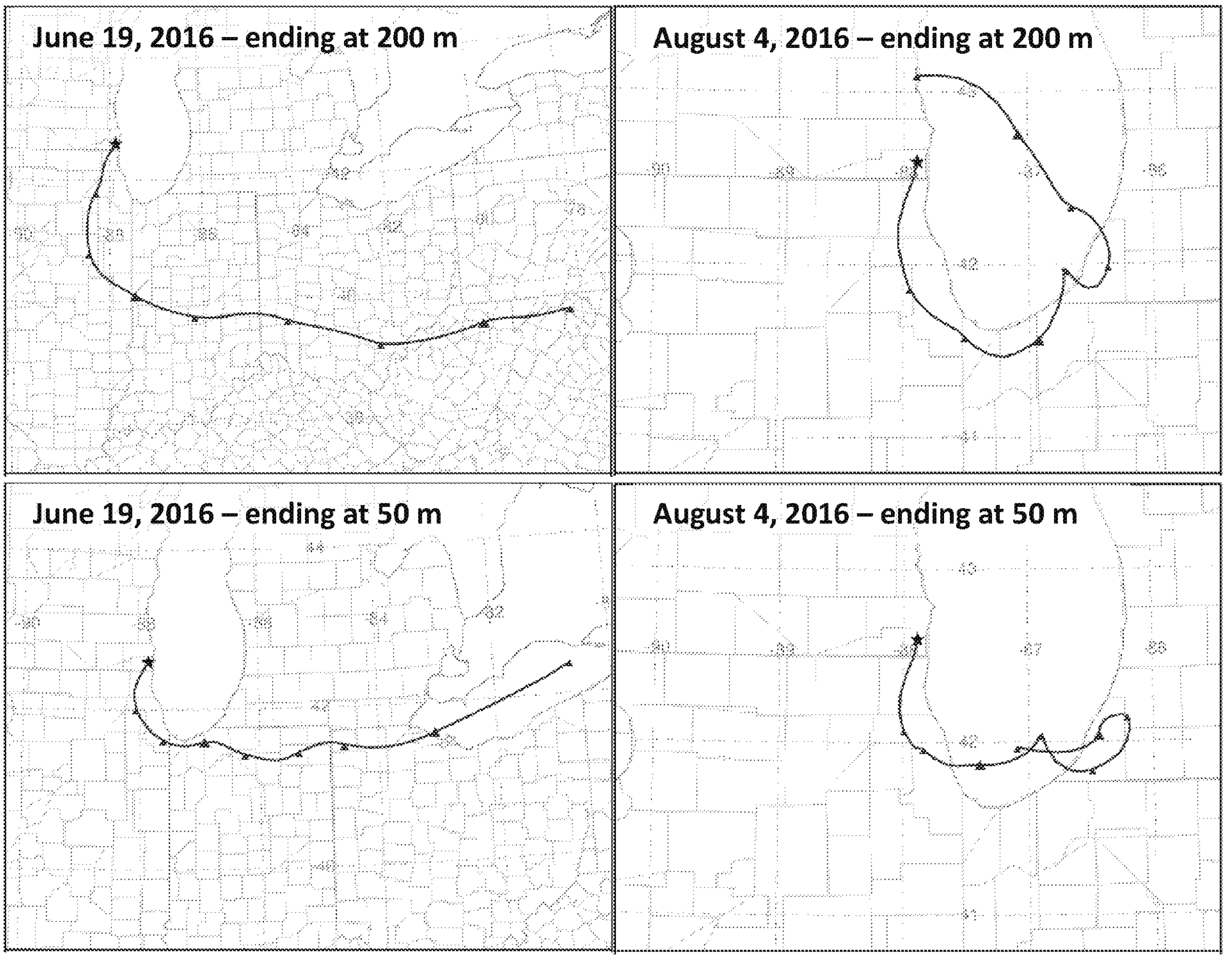
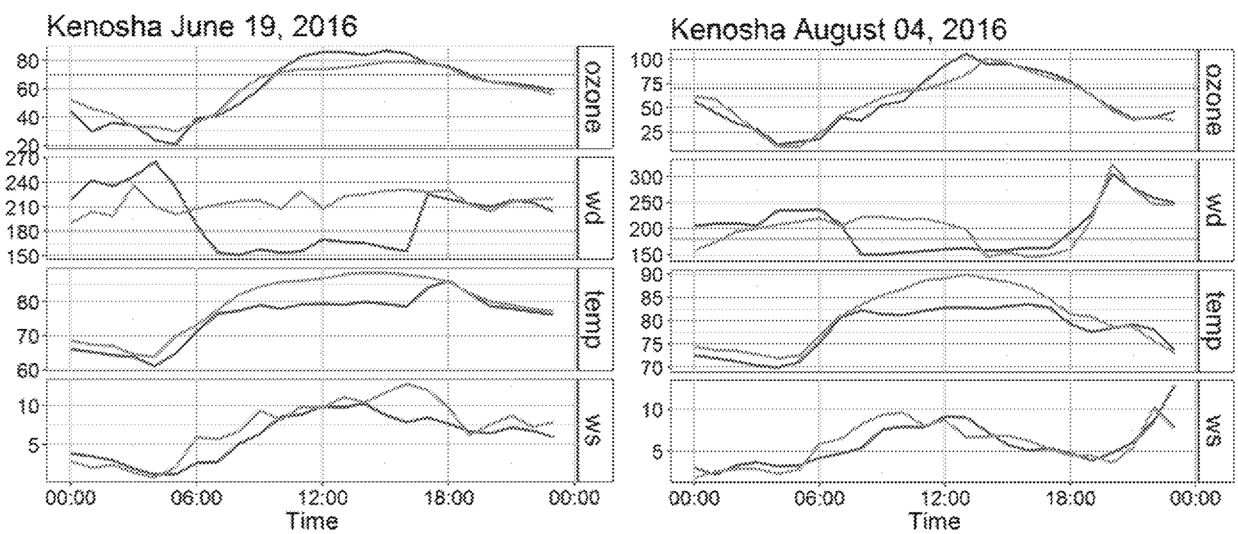


Figure C.6 shows how ozone concentrations, wind directions and other parameters changed at the two Kenosha County monitors during the two days shown in Figure C.5. Figure C.6 (left) shows an example shallow lake breeze day with direct overland transport of ozone to the inland Kenosha Water Tower monitor. On this day, the lake breeze reached the lakeshore Chiwaukee Prairie monitor in the morning and continued through most of the afternoon. In contrast, winds at the inland monitor remained steady from the south-southwest. Hourly ozone concentrations at the inland monitor reached 79 ppb, and hourly lakeshore concentrations reached 87 ppb.

Figure C.6 (right) shows a day with a deep lake breeze and direct transport of ozone from the Chicago area. On this day, the direct transport occurred during the morning and midday hours when winds at the Kenosha Water Tower monitor came from the south-southwest, before the lake breeze impacted this monitor. During the hours of direct transport, 1-hour ozone concentrations at the inland monitor climbed to 84 ppb. Hourly ozone concentrations jumped even higher, to 101 ppb, when the lake breeze reached this monitor.

Figure C.6. Plots of hourly ozone concentrations (ppb), wind direction ("wd", in degrees), temperature ("temp", in °F), and wind speed ("ws", in miles/hour) at the two Kenosha monitors on two days with direct transport of ozone from the Chicago area to the inland Kenosha Water Tower monitor. June 19, 2016 had a shallow lake breeze, and August 4, 2016 had a deep lake breeze. Values for the lakeshore monitor are shown in blue and those for the inland monitor in green.



Temperatures on the days shown in Figure C.6 were very high, reaching 88 to 89 °F at the inland Kenosha Water Tower monitor. It appears that the south-southwesterly winds transported air containing ozone precursors from the Chicago area to Kenosha County, and the high temperatures facilitated the reaction of these precursors to form large amounts of ozone. Such transport occurred during both shallow and deep lake breeze events, with direct transport occurring before the lake breeze reached the inland monitor for the deep lake breeze events. The same patterns occurred on the other identified direct transport days, although both temperatures and ozone concentrations were lower on those days.

The two days shown in Figures C.5 and C.6 (August 4 and June 19) had the highest and fourth-highest maximum daily 8-hour average (MDA8) ozone concentrations of all days in 2016 at the Kenosha Water Tower monitor.[8] This shows that such direct transport events have an important impact on this monitor's design values, which are calculated from annual fourth-highest MDA8 values.

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[8] The highest was on August 4, the fourth-highest was on June 19.

APPENDIX D

Map of the 70 ppb Ozone Design Value Contour

Figure D.1. Map of the 70 ppb design value contour along Wisconsin's Lake Michigan shoreline. The 70 ppb design value contour as described in Chapter 6 of the TSD is shaded. This graphic is identical to Figure 6.1 in the TSD. Page size is set to 11 x 17.